Instruments

THE MAGAZINE OF Measurement and Control

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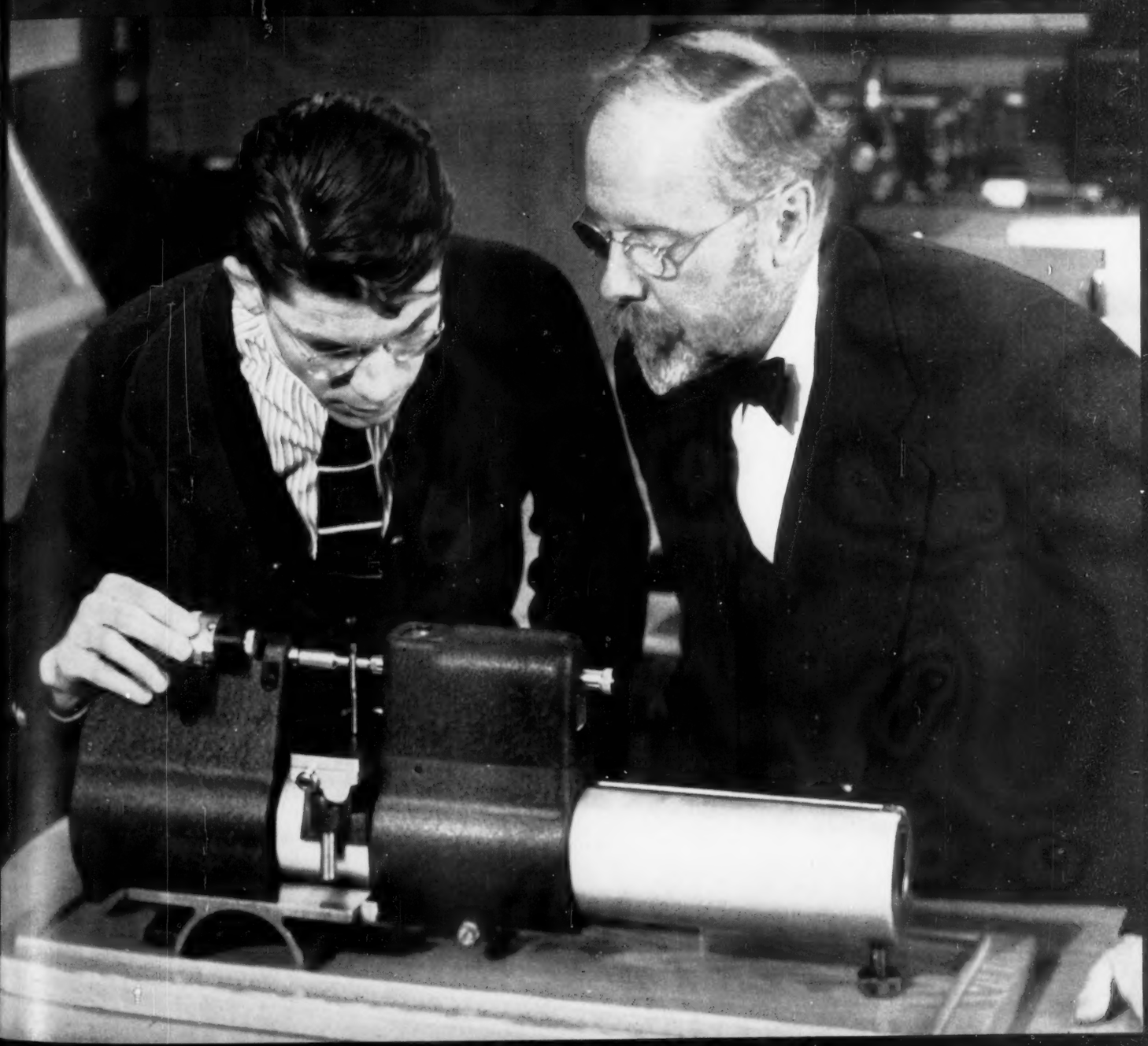
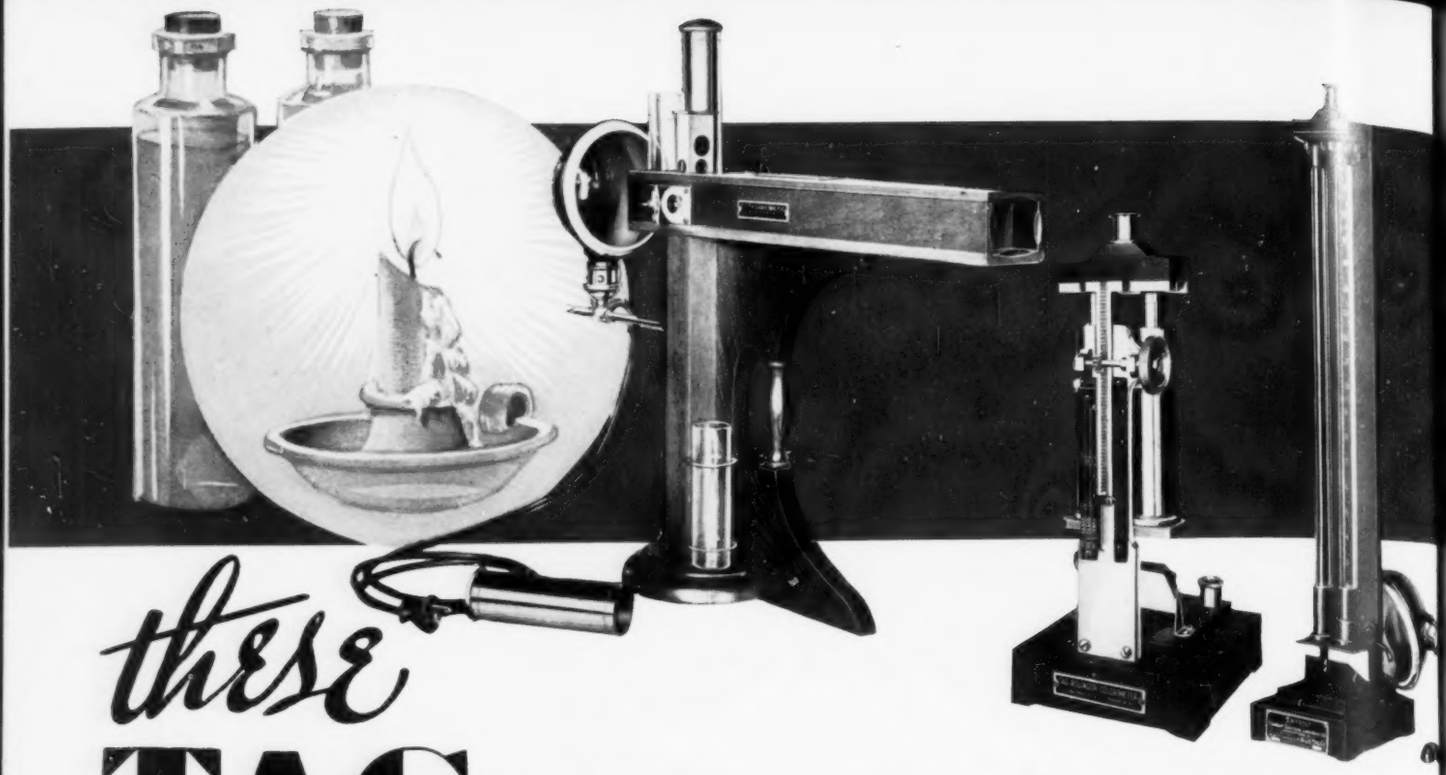
JULY
1940
No. 7





these TAG COLOR INSTRUMENTS

make the sample bottle test as obsolete as Candle Light for Illumination . . .

The two new TAG Catalogs shown above should be on your desk now. No. 1100-I illustrates and describes the regular line of extreme precision and standard grade TAG Thermometers and Hydrometers, and also contains useful conversion tables and instructions for using thermometers and hydrometers.

Catalog No. 699-I illustrates and describes the many TAG Oil Testing Instruments for Petroleum Products. Send for your FREE copies today.

The first oil well in America was drilled by Drake in 1859. Three years later, in 1862, TAG'S first oil tester was patented. In 1864 the U. S. Petroleum Association adopted and recommended the use of the Arnaboldi (later known as TAG) "coal oil" Hydrometer. With that sort of tradition, it is not to be wondered that the TAGliabue organization has played an important role in the development of practically every oil testing instrument of consequence and has been responsible for the introduction of many new pieces of equipment which are now indispensable to the efficient and successful operation of the laboratories of the oil industry.

TAG A.S.T.M. UNION COLORIMETER

Numbered among the many notable TAG Oil Testing Instruments is the A.S.T.M. Union Colorimeter. It is manufactured by this Company as exclusive licensee under agreement with A.S.T.M. It operates on the principle of matching a fixed sample of oil with variable color standards. Comes equipped with 12 color standards, standard glass jars and the new TAG Daylight Lamp. For color determinations of lubricating oils and petrolatum it is universally accepted. Your laboratory is ill-equipped without this standard device.

TAG ROBINSON COLORIMETER

An exclusive TAG product, manufactured in accordance with the specifications of the late C. I. Robinson. This instrument is distinguished from the TAG Union Colorimeter in that it operates on the principle of matching a variable depth of lubricating oil with a fixed color standard. Ideal for plant control and for accurate differentiations of color shades.

TAG A.S.T.M. SAYBOLT STANDARD UNIVERSAL CHROMOMETER

Closely associated with TAG has been the name Saybolt. TAGliabue was originally appointed the sole selling agent for the Saybolt line of oil testing instruments. Later this Company took over the exclusive manufacturing rights for all the instruments developed by George M. Saybolt. Numbered among this group is the Chromometer illustrated above. It operates on the principle of matching a variable depth of oil with a fixed color standard. It is indicated for accurate service in determining color shades of kerosine and gasoline.

TAG MacBETH A.S.T.M. DAYLIGHT LAMP

Ask us about this lamp for use with each of the TAG Oil Testing Instruments described here. It provides a uniform source of daylight illumination.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAG LIABUE BROOKLYN N.Y. U.S.A.

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Now you can check at a glance the level of liquids in boilers, steam accumulators, feed-water heaters, surge tanks and other vessels under pressure . . . reading the figures directly from a clear-cut legible dial. » » » Nothing to break. No blowing down necessary before taking a reading. Operates on a simple differential pressure principle. Safe at any commercial temperature and at pressures up to 1,000 lb. per sq. in. » » » Readings may be conveyed to the most convenient location for the operator. There's no illumination problem, and readability is unaffected by dirty boiler water or foam. Sturdily built for long life with minimum servicing. Dial may be calibrated to read in % of total capacity, gallons, pounds or other units. » » » Where records are desired, Foxboro recorders for liquid level are also available. For complete specifications of this and other liquid level instruments, write for Bulletin 187-3.

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LIQUID LEVEL INSTRUMENTS

Good News!
EARLY
Delivery
(60 days or less)

The world's most accurate pressure gauges

When we announced that Heise Extreme Precision Gauges (formerly used on testing machines only) were placed on the market, some inquirers assumed deliveries would take three to six months because each gauge is hand-calibrated and certified. Please note that two months should be allowed. Better still, write us!

Note. Prices are surprisingly low. Example, $120 for a ten-inch (11¾" O.D.) gauge with 500 graduations.

HEISE Bourdon Tube Laboratories
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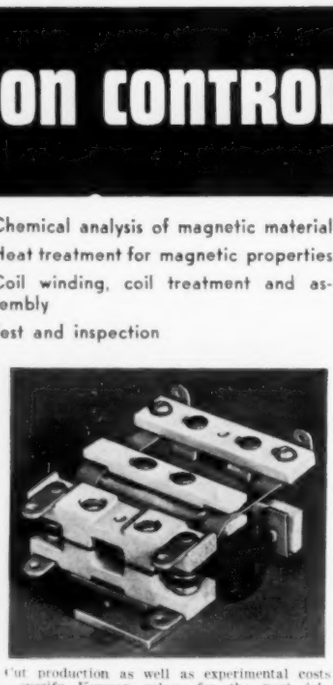
In Collaboration with The A. H. Emery Co.

PRECISION CONTROL

PRECISE

Chemical analysis of magnetic material
Heat treatment for magnetic properties
Coil winding, coil treatment and assembly
Test and inspection

This new "25 relay" — rugged, compact, foolproof—has a low power consumption of 1.5 watts and high power output of 2,000 watts. Developed to fill the need for a high quality medium-duty relay at low cost. Coin silver contacts—¼" diam., Alsimag non-hygroscopic insulation, cantilever spring action, self cleaning wipe.



Cut production as well as experimental costs —specify Kurman relays for the next job. Write for descriptive literature; no obligation.

KURMAN ELECTRIC CO.
INCORPORATED
241 Lafayette Street, New York, N. Y.

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

Vol. XIII JULY 1940 No. 7

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Instruments

THE MAGAZINE OF *Measurement and Control*

M. F. BEHAR, Editor

To Speed Up National Defense

SPEED is recognized as an important factor in national defense. There are three distinct phases to be considered: (1) The time interval between the placing of an order for an item by the War Department or the Navy Department, and the time when quantity production *can* be begun. (2) The *increasing* rate of production of such an item after production is begun. (3) Speeding up contributory services.

Many time factors and speed factors could be described individually, but practically all come under these three phases of "speed."

Patriotic engineers, production men and other specialists are not idly waiting for the United States Government to send them an engraved invitation to submit ideas: they are working out solutions of "speed" problems.

A few readers of *Instruments* are doing so. Every reader should do so. This means YOU.

If the knowledge possessed by all readers of *Instruments* were assembled and imparted to all manufacturing plants, shipyards and arsenals, America would outclass any possible combination of enemies by virtue of the immensely superior rate of preparation, production, transportation and utilization thus made possible.

The readers of *Instruments* are patriotic. Why are they not all actively working out solutions of speeding-up problems and why are not all these solutions being considered?

Because they—and most civilian technical men—say to themselves; "In the first place I don't know where to send my ideas; in the second place my suggestions would probably be pigeon-holed; in the third place it would take years to get action."

Instruments hereby announces a definitely practical method of assembling ideas and of putting these ideas to work. The theme of The 1940 Instrumentation Contest is to be "Speeding Up Defense Through Instrumentation." All our readers—and their friends—are invited to prepare brief descriptions of methods of speeding up production and contributory services.

The contest will probably close in October, but we urge everyone to start now—writing down his ideas; also drawing diagrams, taking photographs or compiling statistics if required to tell the story. Start now!

But do not mail your manuscripts and illustrations until the complete rules are published in the next issue of *Instruments*. These will include instructions for concealing the identity of each contestant by means of a serial number. There will be a coupon in every copy of the August issue, bearing a serial number. No two numbers will be alike. (A supply of other numbered entry blanks will be made available for your friends.)

So watch out for the next issue. If you know others who have ideas, drop us a line ordering a supply of entry blanks for them, and, of course, tell them to start writing their brief essays.

Toward the end of October (date to be set later) a Jury of Award including representatives of important industries will examine all entries and award twelve prizes. But—and this is even more important—every manuscript containing useful ideas—whether prize-winner or not—will be published in *Instruments* or otherwise made available to all facilities concerned.

Automatization

can do much to speed up the industrial side of Defense. YOU are probably applying instrumental methods that should be widely adopted by others. Read how to benefit your country and possibly win a cash prize.

In other words, our plan is to assemble all suggestions for speeding up defense through instrumentation and strive to have these ideas adopted.

This is NOT a duplication of governmental plans pertaining to new inventions. Patentable ideas are not desired in particular, under the projected contest rules. What the Jury of Award will probably prefer is a brief description of *what you are doing at this moment* to speed up your own applications with the aid of measuring and controlling instruments, meters, automatic inspection devices, automatic gages, etc. In other words, if you have put into practice any way of using instruments to speed up preparation, production, transportation, etc.—any way which others can easily copy—then this is the best possible kind of an idea to submit, because, if widely adopted, it will reduce the time lag and speed up production.

Start writing your brief description immediately. Watch out for the detailed rules and regulations in our next issue but don't wait. Start now!—MFB.

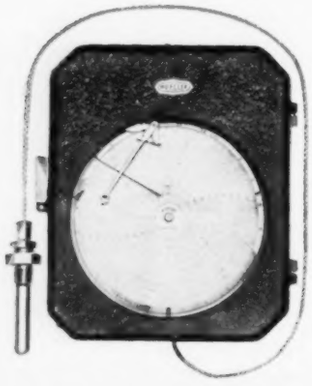
MOELLER
PRECISION GRADE INSTRUMENTS

★

Moeller mercury thermometers are made with the Moeller Glass Red Reading Column making them easy to read under varying light conditions, at a considerable distance and over a wide range.

★

Moeller dial thermometers are made in various scale ranges up to 1000°F. or equivalent. Metal and Phenolite cases.



Moeller recording thermometers are likewise furnished in various ranges up to 1000°F. or equivalent. Round and square cases as preferred.

Also HYGROMETERS
RECORDING PSYCHROMETERS
BAROMETERS HYDROMETERS
MARINE INSTRUMENTS, ETC.

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THE MONTH'S NEW INSTRUMENTS

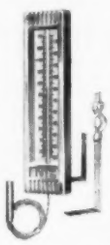
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Radio-frequency Voltmeter

New r-f. voltmeter is said to be unique in that it may be used on power, audio and radio frequencies up to 1500 kc. Employing electrostatic principle, it consumes no energy and is said to be independent of temperature, frequency and wave form. Fitted with a self-contained over-voltage protection to minimize danger of flash-over when used on ordinary power frequencies. Up to 3500 volts, instrument can be directly connected to either a-c. or d-c. circuits. Available specials: 150-volt full-scale model reading down to 20 volts, and high-voltage models in single, dual or triple range patterns up to 25,000 volts. Three standard dials: 2½", 3¼" and 4": three patterns: flush or projecting for switchboard mounting, and portable.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York City.*

Duct Thermometer

Designed for air conditioning applications, new "W59A Thermometer" has a remote bulb with a mounting clip to permit mounting bulb at desired point within duct. Thermometer has universal mounting bracket which allows scale-case to face right, left or front; and to be turned at any angle between vertical and horizontal. Wide red liquid column can be read from a distance of "several feet." Standard range, —30 to +180°F. Finish is polished aluminum. Case is 9" high (scale length 6½"), 2 11/32" wide and 11/16" deep (depth with adjustable bracket is 3¼"). Another model, "W59B," is similar except that its remote bulb is enclosed in a protecting well and is intended for insertion in water pipes or tanks. — *Minneapolis-Honeywell Regulator Co., 2950 Fourth Avenue, South, Minneapolis, Minn.*

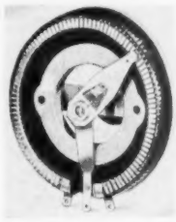


High-pressure Densometer

Permitting testing denser range of paper than can be handled conveniently with maker's regular model Densometer, new "No. 4120 High Pressure Densometer" has the same general purpose: determining porosity of sheet materials in relation to absorption of ink, lacquers, waxes, etc., and to rate of escape of air through pores. Test sample is clamped between two heads. Pressure is applied by a weighted piston in the form of an inverted cylinder, which floats on mercury contained in an outer cylinder. Piston sinks to displace air which is forced through sample and a stop watch reading is taken on 5 cc. graduations marked on piston barrels. Time-porosity relations are standardized.—*W. & L. E. Gurley, 514 Fulton St., Troy, N. Y.*

750-watt Rheostat

"Model T" 50 Watt Vitreous Enameled Rheostat is added to maker's range of Ohmite Rheostats. New unit, filling in between the 500- and 1000-watt rheostats, is 10" in diameter, with a ⅜" shaft. Regularly supplied to mount on panels up to 1¼" thick. Maker's vitreous enameled rheostats are now available in 25- to 1000-watt models in a wide range of resistance values. Available in straight or tapered winding. Single or tandem assemblies, or rheostat cages can be furnished if desired. —*Ohmite Mfg. Co., 4835 Flournoy Street, Chicago, Ill.*

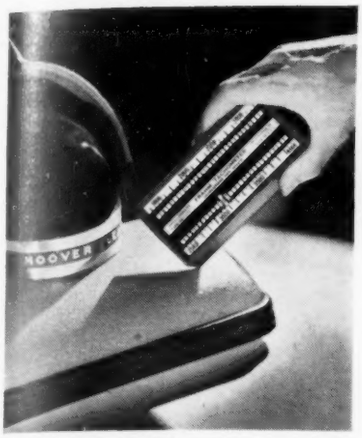


Tubular Capacitors to 2000 Mfd.

New "Type BRH" electrolytic tubular capacitors provide high-capacity units in low-voltage applications, are available in capacities up to 500 mfd. at 25 volts, 1000 mfd. at 15 volts, and 2000 mfd. at 6 volts. They are similar in physical appearance to the maker's "Type BR": vented aluminum container over which a varnished cardboard tube is drawn for protection. Dimensions from ⅝" × 1-1/16" for smaller sizes, to 1" × 2½" for higher capacities. Choice of pigtail or lug terminals.—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

Manual-reset "Mu-Switch"

Lock-out protection is afforded by new manual reset device now available with maker's normally-closed single-pole "Mu-Switch" (See *Instruments*, June 1940, page 147). Manual reset comprises an insulated pin, projecting from switch cover at end opposite actuating button. A momentary pressure of 4 oz. on actuating button opens contact circuit, which remains open after pressure is removed; a touch of manual reset button re-establishes normally closed circuit. Mounted in a sealed housing with flexible diaphragms covering actuating and reset buttons, this style "Mu-Switch" provides on-and-off control under hazardous conditions. — *Mu-Switch Corp., Canton, Mass.*



MEASURE R. P. M.

without even seeing
the rotating element

THE "FRAHM" TACHOMETER

operates merely by being held against or mounted on the machine under test and imposes no load. There are no belts, gears or electrical connections—simply a set of accurately tuned steel reeds which operate by resonance. Various ranges from 900 up to 30,000 r.p.m. Unique also for measuring vibrations per minute.

Write for descriptive Bulletin 1590-I

JAMES G. BIDDLE CO.
ELECTRICAL AND
SCIENTIFIC INSTRUMENTS
1211-13 ARCH ST. PHILADELPHIA, PA.

★ **Moisture Teller** ★

Rapid and accurate moisture test in percentage by drying. Drying temperature controlled by thermostat. Ideal for plant moisture control or laboratory moisture determinations.

Time required to dry the majority of materials is one minute.

Suitable for granular—fibrous—crystaline materials in industries such as:

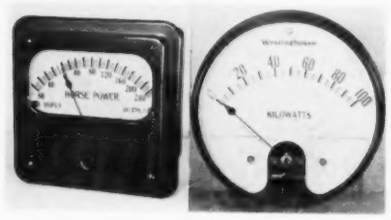
Sand—Textile—Tobacco
Ceramic—Rubber—Food
Wood—Mining—Leather

Write for Literature

Harry W. Dietert Co.
9330-C Roselawn Avenue
Detroit, Michigan

D-c. Wattmeter

A new d-c. wattmeter which operates from a standard 50-millivolt ammeter shunt is announced. Construction is similar to that of usual d-c. shunted ammeter except that



magnetic field is produced by an electromagnet energized from the line voltage. This magnetic circuit is made from Hipernik alloy of iron and nickel. Existing shunts and long, small wire shunt leads as for ammeters, may be used for the current circuit. Instruments are available in conventional 5½" square or 7½" round switchboard cases to match the other switchboard instruments.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

A-c. Capacitors for "Flea-Power" Motors

Designed for starting service with low-voltage, "flea-power" motors, continuous-duty a-c. electrolytic capacitors of the etched-foil, dry electrolytic type, are announced in various capacities up to 50 mfd., all rated at 25 volts. Largest size is 1" × 2⅛".—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

Electronic Bridge

New "Model 575 Electronic Bridge" is said to embody a new conception in bridge measurements: beside being used as a conventional bridge it can be used as a per-

centage bridge and also as a synchrometer; and it permits electrical triangulation not possible with conventional bridges. Circuit, which is shielded, features a cosine galvanometer, has built-in standards and provisions for external standards. Galvanometer cannot be injured by extreme unbalance of the bridge. Although it operates on a.c., new bridge has null balance as all standard d-c. bridges. Measurements include capacity, resistance, inductance, impedance, power factor and frequency. Sensitivity is such as to permit detecting change in capacity of 1 $\mu\mu$f. Bridge measures capacity beyond 1000 μf. Measurements to 500 megohms are by true bridge balance. Electron tubes are supplied with the instrument.—*The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*

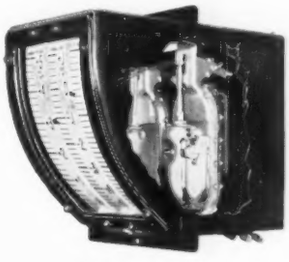
BAILEY METERS

METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Reduce fuel costs, lessen maintenance and outage, lower standby costs, and add capacity. They indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

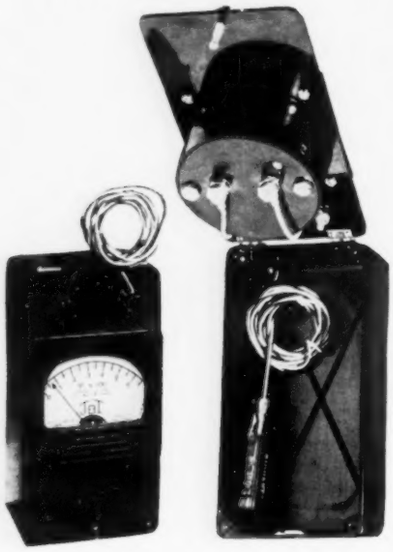
Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-14

BAILEY METER • COMPANY •
1041 Ivanhoe Rd., Cleveland, Ohio
BAILEY METER COMPANY LTD., MONTREAL

Portable Indicating Pyrometer

Pocket-size portable indicating pyrometer, "Model 32-JP," designed for measuring temperatures of appliances, electric and gas ovens, transformers, etc., is suitable also for



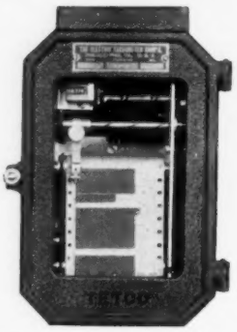
laboratory applications wherever the small thermocouple tip can be inserted. Instrument, housed in a rectangular black plastic case, is a special Triplett milliammeter (made to J-B-T specifications), automatically compensated for ambient temperature by the bi-metallic method. Scale, 2.38" long, has 0-650°F. range; other ranges available on special order. Black outer case is molded plastic, 3-1/16" × 5⅞" × 2⅛", with rounded corners. Hinged cover permits thermocouple and equipment to be carried inside. A leather carrying case with leather handle is also available. Instrument comes with 3½' insulated iron-constantan thermocouple wire, No. 22 gauge. Special lengths are made to order. Pyrometer alone, known as "Model 32-J," in molded case with front 3" × 3", can be ordered for separate panel mounting or on laboratory stand.—*J-B-T Instruments, Inc., 441 Chapel St., New Haven, Conn.*

Capacitor Analyzer

New "Model BF-50" Capacitor Analyzer is an entirely self-contained instrument for checks and measurements on every important characteristic of all types of capacitors.

It also permits measurement and analysis of other circuit components such as cabled wiring, shielded leads, transformer windings and insulation, etc. Measurements provided for include: capacity (10 mmfd. to 240 mfd.), power factor (0 to 50%), insulation resistance to 1500 megohms, leakage, shorts, open or intermittent conditions, etc. A Wien Bridge arrangement assures permanent calibration and independence of line voltage variations. Balance is indicated by a "visual eye" with a 12A7 amplified built into the analyzer. Also built-in is a d-c. power supply of approx. 450 volts for use in leakage and insulation resistance measurements.—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

TETCO
Speed Recorder



Creates a permanent time record on a waxed chart. Accurately records rate of production, time and duration of stops, total quantity produced.

The Electric Tachometer Corp.
1358 Spring Garden St., Philadelphia, Pa.

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done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 30 years.

In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

Illustrated bulletins free.

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TRU-VAC
VACUUM GAUGES
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Priced From $39.50
Circular on Request.
CONTINENTAL ELECTRIC CO.
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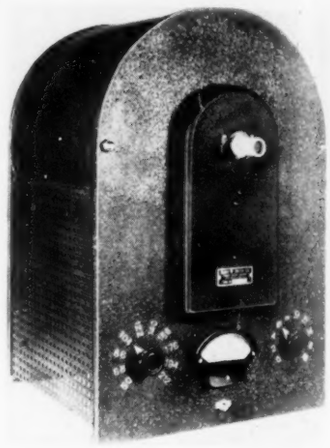
INTERVAL TIMERS
PROCESS TIMERS
SIGNAL TIMERS
TIME SWITCHES
FLASHERS
Write
AUTOMATIC Electric Manufacturing Co.
Mankato, Minnesota

Combustion Furnace

Designed for carbon and sulphur determinations by combustion method of all metals, new "Varitemp Combustion Furnace" is also adaptable for combustion of coal,



coke and oils for determination of sulphur with Leco Sulphur Determinator. Furnace, transformer, pyrometer, voltage control switches and power switch are all built into one unit and housed in a single case. Furnace uses three Globar heating elements placed equidistant around the outside of the combustion tube. A uniform high temperature zone 6" long is obtained in the combustion tube. This tube is securely held on each end by means of a clamp faced with an asbestos gland. Electrical wiring, switches and transformer are all enclosed and well ventilated. On the front of furnace are two rotary switches for selecting proper voltage to maintain desired temperature. Voltage imparted to heating elements is equal to sum of switch pointer figures. It may be increased from 50 to 230 volts in 2-volt steps. Temperature is indicated by a fan-shaped compensated pyrometer on front of furnace. A platinum-platinrhodium thermocouple is used. Furnace is 16" in diameter, with insulation to conserve electrical power. (Max. 750 watts.) There are no exposed heated parts or electrical parts to form a hazard to operator. Overall height, 25"; overall length, 17"; standard combination tube, ¾". —*Harry W. Dietert Co., 9330-C Roselawn Ave., Detroit, Mich.*

Portable Polariscope

New glass strain detector is said to be extremely sensitive, showing compression and tension strains in opposite colors so that existing strains may be analyzed and

their causes determined. As illustration shows, this form of polariscope is adaptable to examine glass of any size or shape that is transparent or semi-transparent. Dimensions, 6" × 6" × 6", with a 5" × 5" screen. Weight, 3½ lbs.—*Xervac Instrument Co., 650 Main St., Hartford, Conn.*

Individualized to meet your specific instrument design specifications.

Clare Relays are available in innumerable coil, contact, adjustment and timing combinations — accurately made of quality material.

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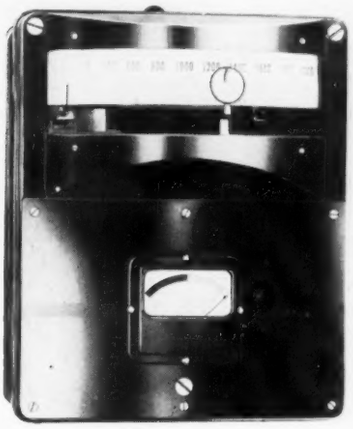
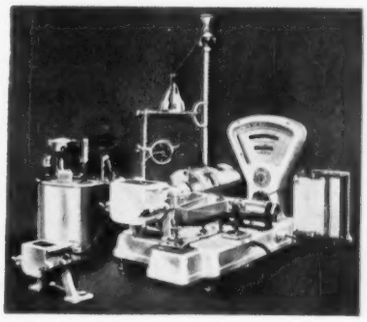
Pyrometer Controller

New "Model 486 Electronic Controller," for industrial furnaces, ovens and kilns, employs a contact-less and drag-less electrical relay whereby pointer of measuring system



commands control circuit continuously, while remaining free at all times and at all points of working range. This relay consists of a small vane mounted under temperature-indicating pointer; and of two small coils mounted upon "spotter arm" which marks and determines control point. When vane passes between these two coils, their mutual inductance is varied. These two coils form part of an oscillatory circuit, so that variation in mutual inductance causes variation in amplitude of oscillation. Mechanical design (particularly narrowness of coils) and electrical constants are such that a change of almost 100% in mutual inductance is effected by relatively small displacement of vane, corresponding to displacement of pointer over a few degrees of temperature (this number of degrees depending on length of pyrometer scale). Variations in air temperature and humidity do not affect operation. Oscillatory circuit employs a high-output all-metal vacuum tube, whose output decreases as vane passes through coils, thereby actuating a "Millivac" vacuum contact type load relay with contacts rated at 5 amps. at 110 volts a-c. non-inductive load. A milliammeter on front of controller amplifies pyrometer scale around control point, shows when relay is in on or off position, indicates condition of vacuum tube.—*The Bristol Co., Waterbury, Conn.*

PLASTOGRAPH



Recording Plastometer—based on the dynamometer principle and practically "weighing" the plasticity of the different materials. Measures consistency over a wide range of materials—from fairly viscous, syrupy substances to unvulcanized rubber. Has been applied successfully in RESEARCH as well as in PLANT CONTROL (for continuous operation) in the following industries:

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Can be supplied with various types of mixers or agitators—all water jacketed for efficient temperature control. Has three different sensitivity settings and can measure and record within each desired range with three times and five times increased sensitivity by the simple expedient of zero-suppression.

Pamphlet on Request

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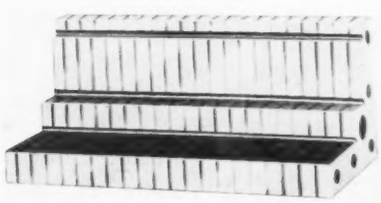
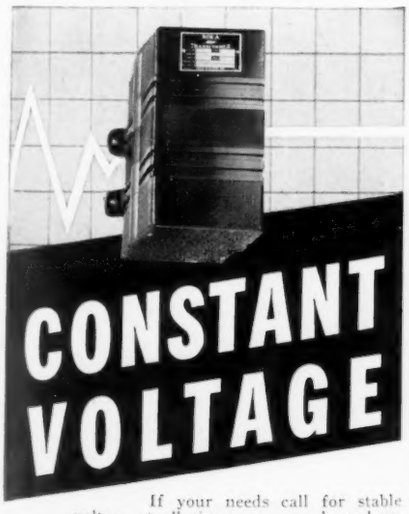
Universal Angle Iron

Added to maker's line of "Magne-Blox" products is new Universal Magne-Blox Angle Iron, for magnetic chucks, designed for holding diversified work of all types. It



consists of a series of steps measuring in width 3/16", ⅜", ½", 1-5/16", 1⅝" upon which may be placed various special pieces for surface grinding without use of complicated clamps, etc. Overall dimensions are 3" × 3" × 7½". It eliminates setting-up time for grinding small pieces, may be used for grinding all four sides of a square. When placed on plane surface of magnetic chuck, new angle iron will actually form a magnetic right angle which gives same holding power per square inch as chuck itself.—*George Scherr Co., 128 Lafayette St., New York City.*



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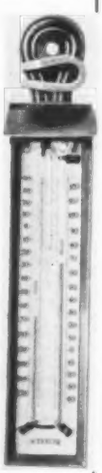

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(Left) No. 169. For pressure-cooking processes, with two scales: 170-270°F. and 0-30 lbs. pressure. 9" scale length.

(Right) No. 326. Max. & min. registering thermometer in 12" shelter type copper case. Approx. range minus 40 to 120°F.

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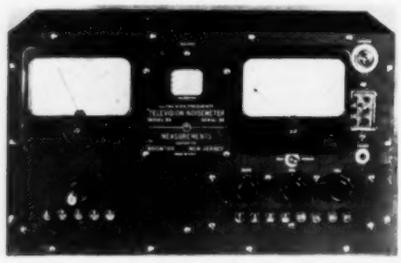
Radio Set Tester

New "Model 133" portable radio set tester has among its features a 40-microampere range; a portable dry battery testing circuit; a new high-torque movement especially designed for supersensitive radio equipment; a 5" square indicator with scale opening and four-color scale. Ranges are as follows: 40-500 d.c. Microamperes, 5-50-500 d.c. milliamperes, 2.5-10-50-250-500-2500 volts a.c. and d.c. 25,000 ohms per volt d.c. 1000 ohms per volt a.c. 0-30-10,000—1 meg. —10 meg. resistance. Decibels. All ohmmeter ranges operate from self-contained batteries. Battery tester for testing batteries in all popular sizes up to 135 volts.—*The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*

Television Noise Meter

New "Model 58 Television Noisemeter" is designed in accordance with recommendations of R.M.A. Sub-Committee on television interference. Pass-band is wide enough to permit accurate field-strength measurements of FM signals down to levels of a few microvolts per meter. In width of pass-band and time constants of weighting circuits, Model 58 is said to represent improvement over earlier instruments, permitting ignition noise measurements closely approaching peak values and hence true nuisance value of ignition and other pulse-type noise. Measurements can be made on wobbly diathermy signals and harmonics, also of any ultra high frequency carrier in its range. Principal characteristics include: 15 to 150 Mc. in five bands with dial calibrated in Mc.; 1 to 100,000 mv. measuring range across 70-ohm line; 1 to 100 microvolts on semi-logarithmic output scale. Balanced resistance attenuator with ratios of 10, 100, and 1000 ahead of all tubes. Gain standardization from internal "shot noise" diode; calibration dial obviating need for charts; tuned r-f. amplifier eliminating image response; provision for direct operation of a 5 milliamp. recorder; push-button switching throughout; operation from either 115-volt a-c. or 6-volts d.c. Standard equipment includes power cables, 15' antenna cable, 9" loop antenna, etc. Panel is 9" × 16", depth, 11"; weight: 27 lbs.—*Measurements Corp., Boonton, N. J.*



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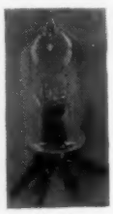

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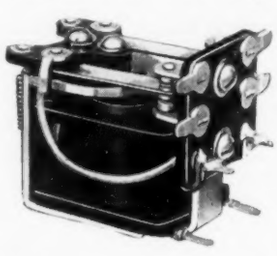
Low-voltage "Tattelite"

A new low-voltage "Tattelite" pocket tester has been designed to cover the ranges from 3 to 25 volts, momentary up to 50 volts, a.c. or d.c. It uses a high temperature coefficient lamp to cover this relatively wide range of voltage. Lamp is housed in a molded, transparent tenite case. It has tinsel wire leads, and alligator clips. Draws 70 mils. @ 12 volts. While designed primarily for use on 24-volt control systems in heating and air conditioning, largest field is circuit checking in airplanes, motor vehicles, telephones, storage battery circuits, etc.—*Littelfuse, Inc., 4757 Ravenswood Ave., Chicago, Ill.*

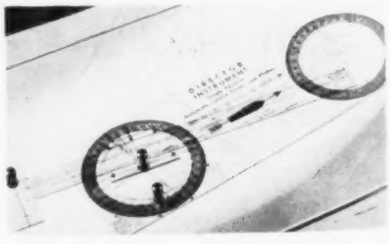
Midget Relay

Noteworthy characteristics of new midget relay, it is claimed, are high d-c. efficiency, hum-free a-c. operation, and a wide range of coil voltages. Dimensions are 1½" × 5/8", and mounting, on any type of panel, is permissible due to ungrounded construction. Installation is accomplished by a single 6/32 stud. Where some degree of sensitivity is desired, positive service may be attained on 0.1 watts, with a safe continuous-duty rating of plus two watts without danger of over-heating. Contact combinations are dp-st or dp-dt, employing ⅛" silver contacts to handle up to 200 watts on non-inductive a-c. loads. Coil and line connections are made to tinned solder lugs.—*The Advance Electric Co., 1260 W. 2nd St., Los Angeles, Calif.*



Aircraft Navigation Instruments

When every minute means traveling over three miles, fast and accurate calculations are required. New navigation aids for aircraft (and small boats) made available with advent of permanent, non-warping "Vinylite" plastic sheet, are designed for both calculating and sighting a course. The "Director" instrument is shown in accompanying illustration. Lettering will never scratch or blur for it is protected by an over-lamination of "Vinylite" resin film.—*Director Instruments, New Haven, Conn.*



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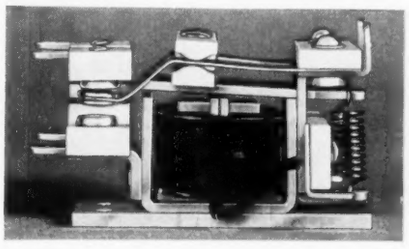
Phase Sequence Indicator

Consists of a small three-phase induction motor mounted in a Bakelite case and fitted with an aluminum disk which "instantly" indicates direction of phase rotation on a three-phase supply. Portable model can be readily carried in a pocket, is fitted with three 30" leads with Mueller clips, numbered 1, 2, 3. Switchboard mounting models can be supplied also, in either of the 2½" flush or projecting patterns. These instruments can be used on lines from 110 to 550 volts, 25 to 125 cycles; are said to be particularly useful wherever it is necessary to know the phase rotation of a three-phase circuit.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York City.*

A-c. and D-c. Relays

New "No. 25" series of relays has been developed to meet specifications calling for high r-f. insulation, medium contact load, low power input, ruggedness and compactness. Under life test, adjustments maintained for more than 7,000,000 operations and heat rise was less than 25°F. Contacts are puresilver, ¼" diam., will carry 10 amps., 110-v. 60-cycle. Alsimag insulation is non-hygroscopic, 5000 volts to ground. Capacity to



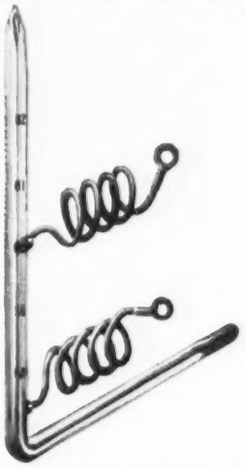
ground 2 mmf., between contacts 0.5 mmf., between poles 1.5 mmf. Input 1.5 watts d.c. or a.c. with 25 g. pressure on each back contact, 0.06" gap. By proper cross connection, relay may be used as s-p., s-t. or d-t., multiple or series break. D-p. d-t. models also available.—*Kurman Electric Co., Inc., 241 Lafayette St., New York City.*

P-f. Correction Capacitors

Comprehensive line of capacitors for power factor correction applications in fluorescent lamp circuits includes three general types, varying in dimensions to fit wiring channels

and in capacity values to satisfy p.f. correction requirements. "Type KF" capacitors are 2¼" wide by 1¼" thick, vary in length from 3" (for 3 mfd.) to 13½" (for 28 mfd.), are available in seven values from 3 to 28 mfd., with voltage rating of 240 except for the 6.5, 11 and 28 mfd. units rated at 120 volts. "Type KS" measures 2-1/16" × 1", eleven capacity values from 2 to 8 mfd. with container lengths from 3" to 6½": all units rated for service on 120-240 volt lines. "Type KW" is identical with the "KS" but width is 1-7/16", thickness 1⅛" and spacing between terminal centers 9/16". —*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

For Extremely Close Temperature Control
Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

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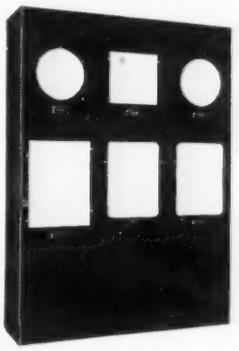

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Light Meter with Electronic Amplification

Response to light values far below the range of conventional photometers is claimed for new "Photrix" Small-spot Photometer with electronic amplification. It

Fig. 1

operates on a.c. or d.c., is balanced for line voltage variations without use of batteries or voltage stabilizers for power supply, is designed particularly for measuring low values of illumination on small areas (example, a small spot of an unevenly illuminated surface). High-gain amplification makes it possible to use "a rugged microammeter" as indicator. Sensitivity is said to be about 1000 times higher than that of a conventional photometer using a barrier-layer cell directly connected to the same microammeter. Outfit is a portable unit comprising instrument proper and search unit. Latter houses phototube and is provided with a turnable disk having various openings used to obtain four sensitivity ranges in ratio of 1, 10, 100 and 1000. Two different models of search units are available: for incident light, of round flat box shape; for transparent light, of tubular shape with a pointed light intake. 100-division scale of indicator (Fig. 2) is 3¾" long, shows deflection reciprocals. At highest sensitivity range, each division represents 0.0005 ft.-cdl. This makes new photometer suitable for measuring fluorescence, luminescence, weak u-v. radiation, Tyndall light, etc., also as the light-sensitive part of colorimeters, densitometers, spectrophotometers, etc.

Fig. 2

Amplifier: Photometer's line-operated, stabilized, high-gain d-c. amplifier lends itself for use in other measuring instruments wherever voltages or extremely small currents are to be measured in a high-resistance input circuit, as in vacuum-tube d-c. voltmeters, insulation meters, pH meters, ionization current indicators, etc. It is said that in conjunction with an inexpensive current indicating instrument, d-c. amplifier can replace extreme-sensitivity galvanometers as a null indicator or as a direct-reading instrument.—*Photovolt Corp., 10 East 40th St., New York City.*

Carbonation Controller

For bottlers of carbonated beverages, "Carbonation Controller" automatically gives uniform gas volume to the carbonator regardless of changes in water temperature or pressure in gas cylinders. Setting for various gas volumes is done by turning knob at front of case. Plants bottling a variety of products develop a setting for each product. Once this setting has been determined, controller will always deliver desired carbonization, it is said.—*Manning, Maxwell & Moore, Inc., Bridgeport, Conn.*

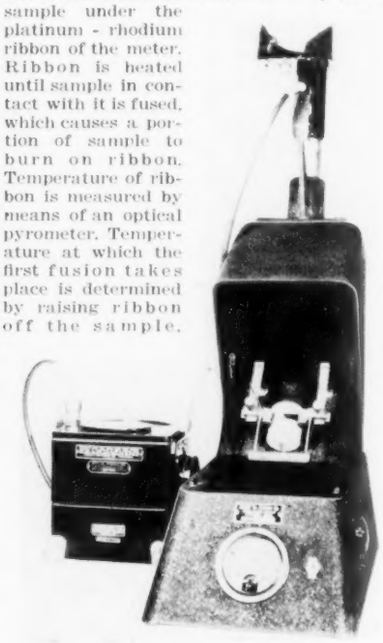
Power Resistor Decade Box

A power resistor decade box which can be inserted in actual circuits to simulate working conditions to simplify and expedite selection of correct resistance values "for any circuit or condition," is intended primarily for laboratory use, calibration and

development work generally. Resistance range covers 1 to 999,999 ohms at a maximum of 1000 volts, by means of six decade switches. Each decade will dissipate up to 225 watts. "Greenohms" (cement-coated wire-wound power resistors) are used for the resistance elements, together with glass-insulated wire for connections. Maximum current per decade is as follows: No. 1, 5 amp.; No. 2, 1.5 amp.; No. 3, 0.5 amp.; No. 4, 0.15 amp.; No. 5, 0.05 amp. No. 6, 0.005 amp. New instrument is said to be "of laboratory instrument grade throughout." A grille at bottom, and louvres at sides and top, provide ventilation of resistance units. A baffle plate protects switch mechanism from heat. Dimensions, 13" × 8½" × 5¾" high; weight, 11 lbs.—*Clarostat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.*

Refractoriness Meter

New "Sinter Meter" is an apparatus for determining the refractoriness of molding sands, clays, refractory mortars and bricks, etc. Refractoriness is determined by placing sample under the platinum - rhodium ribbon of the meter. Ribbon is heated until sample in contact with it is fused, which causes a portion of sample to burn on ribbon. Temperature of ribbon is measured by means of an optical pyrometer. Temperature at which the first fusion takes place is determined by raising ribbon off the sample.



When fusion takes place, ribbon adheres to sample. Ribbon is electrically heated and current is controlled by means of a transformer and Varitran. Incipient fusion temperature determined is termed "sintering temperature" and the test is made in accordance with A.F.A. specifications.—*Harry W. Dietert Co., 9330-C Roseland Ave., Detroit, Mich.*

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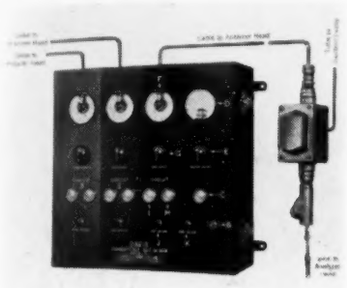
Continuous Combustible Gas Alarm System

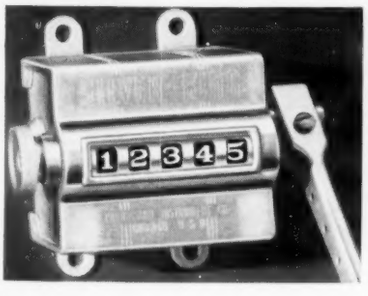
New Davis Continuous Combustible Gas Alarm System is designed to register combustible gas-air or vapor-air concentrations under the conditions in which they exist. It consists of three main parts: (1) Indicator



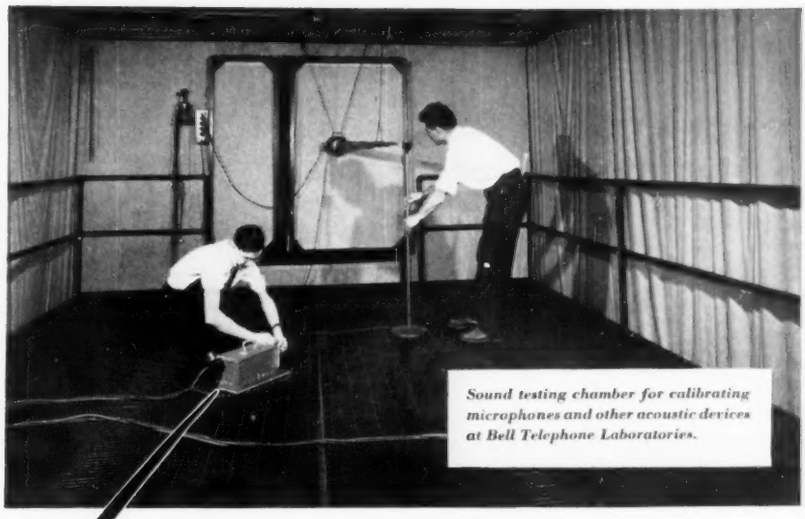
head or heads placed in the location to be sampled. (2) Panel box in and on which are located: a) Voltmeter, b) relay meter, c) relay controlling alarm, b) rectifier and transformer, c) control switches and buttons, d) buzzers which sound alarm should "open" occur in bridge circuit—as blown out filament. (3) Pump which draws the sample into the indicator heads. Indicator head, an explosion-proof housing, contains active and comparison filaments. Both inlet and outlet sides of chamber into which continuous sample is drawn are protected by flashback arrestors. (Special flame arrestors are available for hydrogen-oxygen or acetylene-oxygen.) As cover of housing is removed, a switch is opened so that the filaments may be safely changed in a hazardous atmosphere. Panel box may be located in any gas-free area where most convenient. Special attention is called by maker to illuminated bullseye which shows blue and sounds buzzer when there is any "open" in the bridge circuit. An optional feature is that when an alarm sounds, showing hazardous conditions, a separate relay may be caused to close starting up ventilating equipment to reduce gas or vapor air content; or apparatus may be shut down. In such a case there is an additional push button on face of panel by depressing which the ventilating equipment may be shut down or the apparatus started.—*Davis Emergency Equipment Co., Inc., 55 Van Dam St., New York City.*

Mechanical Counter

New mechanical counter of advanced design has been named the "Silver King." Each operating function, it is said, has been thoroughly studied and perfected. Heavy



number wheels are replaced by Bakelite, reducing by 85% the weight that must be started and stopped with every count. Unbreakable windows of reinforced plastic material are said to be streamlined to avoid shadows. Four years' design effort, it is said, has produced something entirely new in a mechanical counter: first model on test counted at 60,000 per hour, and on long runs at 36,000 per hour.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago, Ill.*



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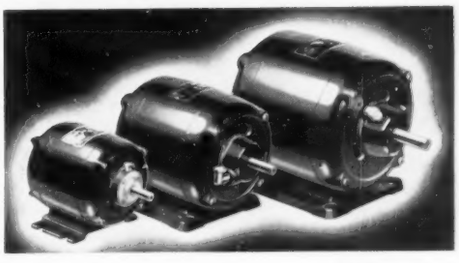

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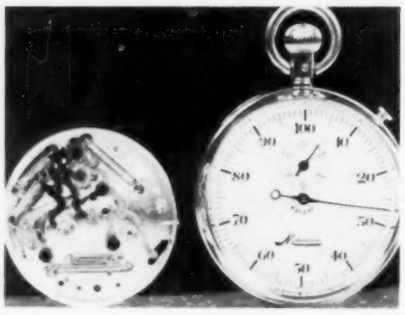
Industrial Timers

New "Coil-spring Mechanism Stop Watch" is announced as marking definite improvements in construction and characteristics affecting accuracy and dependability under



industrial service conditions as well as aviation and sports service. Use of non-breakable, rust- and corrosion-proof coil-springs (illustrated at left) is said to eliminate friction and wear and to assure continual accuracy and longevity. In addition, these time recorders incorporate an independent hammer spring and brake system: the former said to assure life-time fly-back to zero, and the latter to eliminate any variation at zero setting when watch is started or stopped. Model illustrated at right is "No. 111" with dial divided into 100 parts, long hand completing turn in 60 seconds.—*M. Ducommun Co., 580 Fifth Ave., New York City.*

Multi-range Tester

New "Series 832" Rotary Selective A-c, D-c, Tester has thirty-one ranges: six d-c. voltage to 1200, six a-c. voltage to 2400, four d-c. current to 600 milliamps, three

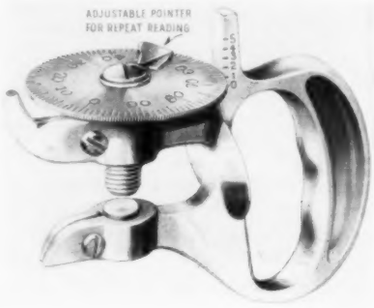
resistance ranges to 5 megohms, to 500,000 ohms on internal 3-volt battery, six decibel ranges from —10 to +62, six output ranges to 2400 volts. Dimensions 7″ × 4½″ × 3″. Extreme simplicity of operation is emphasized in announcement.—*Precision Apparatus Co., 647 Kent Ave., Brooklyn, N. Y.*

Refined Prong-base Electrolytic Capacitors

Refinements and improvements in prong-base electrolytics are embodied in new "Series AF units," superseding "F" series: positive sealing of base and prongs; minimization of possible corrosion; and better mechanical construction obviating shearing of tabs and loosening of internal connections. First departure from conventional is square can shoulder in place of sloping, to insure solid seating of plug or disk and eliminate danger of shearing cathode-tab. Instead of two Bakelite disks separated by a sheet of flat rubber, "AF" construction employs a cup-shaped molded soft-rubber disk with side walls, which rests on square shoulder and against can walls, and into which the single Bakelite disk fits. Rubber disk has several slotted sleeves which slip into slots of the Bakelite disc. Through these rubber sleeves pass the anode or positive tabs. This construction provides rubber-sealed tabs. Dissimilar-metal joints between tabs and lugs being sealed and protected by soft rubber sleeves, no electrolyte can reach them to cause corrosion. Among other features: spot-welded connections, sealing against electrolyte seepage, positive pin-hole vent responsive to excessive gas pressures while normally self-sealing.—*Aerovox Corp., New Bedford, Mass.*

Dial Micrometer for Sheets

Designed for steel mill sheet finishing and shipping departments, new Haines Dial Micrometer is announced as supplementary to maker's line of automatic micrometer



rolling mill gages. It has a 2″ dial with graduations readable at arm's length in thousandths or other gage standards; is held in right hand with fingers through handle and is operated by rotating dial by thumb or forefinger. Special feature is an adjustable pointer, on top of dial, which can be set at any specified gage on the dial. Then, in gaging material, operator has an immediate check if pointer falls opposite the reading post, or knows his material is plus or minus if pointer falls right or left of the reading post.—*Haines Gauge Company, 119 So. Fourth Street, Philadelphia, Pa.*

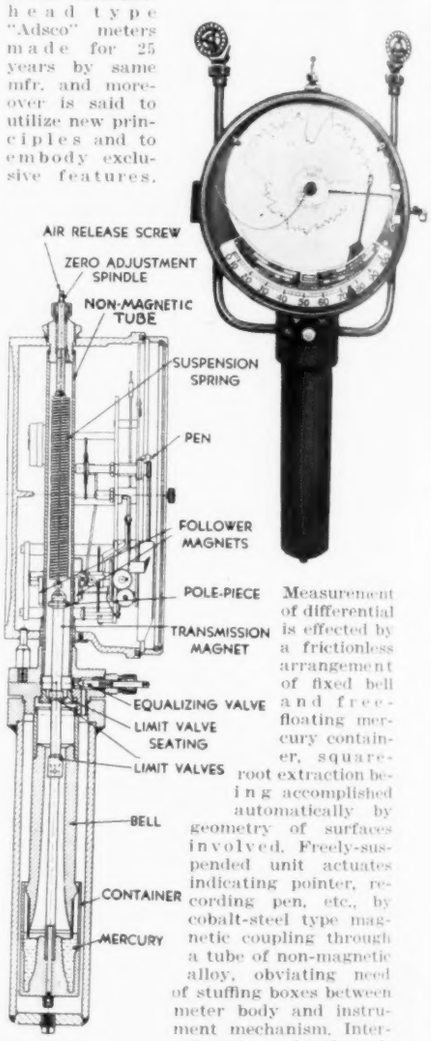
Multiple-purpose Tester

Maker's "Model 414 Universal DeLuxe Multitester" is now available in four additional styles: "Model 414 Series V7" has a 7¼" Bakelite square indicator with jewel

indicating light, and front panel screw cap holder for immediate replacement of "meter" fuse. "RCP Model V9" is the same, except that indicator is the 9" "Jumbo" round type. Similar to V7 is "Model RP7," except that panel is arranged horizontally for rack mounting and there is no overall case: the "414" unit (less indicator) is housed in an open-faced case and may be instantly removed from the panel. "Model RP9" is identical to "RP7," except that indicator is 9" round form.—*Radio City Products Co., 88 Park Place, New York City.*

Uniform-scale, Magnetic-coupling Flowmeter

Announcement is made of a new line of indicating, recording, integrating and combination flowmeters, for steam, liquids, air and gases. Operating in conjunction with an orifice or other differential producer in pipe line, new "Adsco" flowmeter thereby differs from constant-head type "Adsco" meters made for 25 years by same mfr. and moreover is said to utilize new principles and to embody exclusive features.



Measurement of differential is effected by a frictionless arrangement of fixed bell and free-floating mercury container, square-root extraction being accomplished automatically by geometry of surfaces involved. Freely-suspended unit actuates indicating pointer, recording pen, etc., by cobalt-steel type magnetic coupling through a tube of non-magnetic alloy, obviating need of stuffing boxes between meter body and instrument mechanism. Internal contour of bell maximizes mercury surface at minimal rates of flow, so that resultant force is adequate for actuating pointer and pen-arm at lowest flow rates where accuracy is desired. Integrating mechanism imposes no drag at all on metering elements, being powered by a synchronous a-c. motor (as is recording mechanism). Meter body, case and instrument movement are independent assemblies. Conversion of a meter from one model to another is facilitated. Equalizing valve, limit valves, zero adjustment, strainers, internal illumination and other safety and convenience features are provided. Recorder charts, all 11″ diam., are available in 60 standard ranges. Integrator gives direct readings on five-digit register in any desired units, employs a positive mechanical principle of operation and a fundamental geometric principle of cyclic integration: "no amount of wear or ill-usage short of actual mechanical damage can affect accuracy of mechanism." Six types of orifice, nozzle and Venturi primary-device assemblies are available, as well as cooling chambers for steam work and other installation accessories. An auxiliary pressure recorder can be fitted to any model to record working pressure on same chart as flow rate.—*American District Steam Co., North Tonawanda, N. Y.*

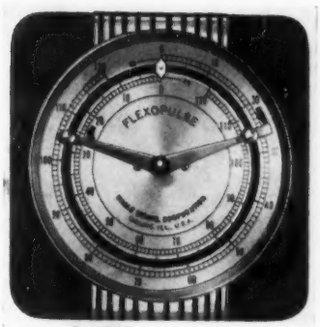
Volt-ohm-milliammeter

Push-button switching by a simpler way is said to make new "Model 1200-F" an entirely automatic volt-ohm-milliammeter. Only one button need be pressed for any range and test setting. Ranges and characteristics: D-c volts, 0-10-50-250-500-1000 at 25,000 ohms per volt; A-c. volts 0-10-50-250-500-1000 at 1000 ohms per volt; D-c. milliamps. 0-1-10-50-250; D-c. microamps. 0-50 (through separate jacks); Resistance 0-500 low ohms, shunt type circuit; 0-300,-000 ohms; 0-3 and 0-30 megohms, series

type circuit. Self-contained batteries for all ranges. Output readings available on a-c. voltage ranges, through a built-in $\frac{1}{2}$ mfd. capacitor. This is said to be the first tester on which only one button need be depressed to make any test.—*The Triplett Electrical Instrument Co., Bluffton, Ohio.*

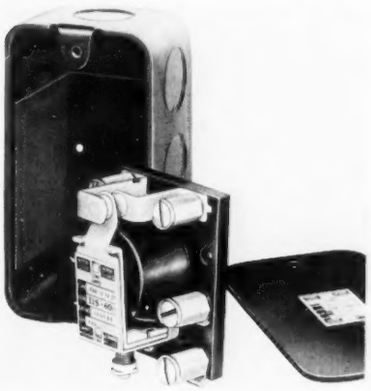
Repeating Cycle Timer

New "Flexopulse" is a repeating cycle timer which utilizes reversing action without reversal of motor to provide what is said to be an extreme range of contact in a continuously repeating series of operations. It is designed to control motors, lights, valves, electric furnaces, temperature controls, etc. One feature of timer's design is that the cycle and percentage of contact closure time may be adjusted without changing gears or adjusting cams. Three models are available, providing ranges of 2 — 120 seconds, 20 seconds — 20 minutes, and 2 — 120 minutes. Models may have s.p.s.t. switch or s.p.d.t. switch. All models have $5\frac{3}{4}$" diam. clock face dials with time adjustment arms for cycle regulation. One adjustment arm regulates length of closure, the other regulates length of opening.—*Eagle Signal Corp., Moline, Ill.*



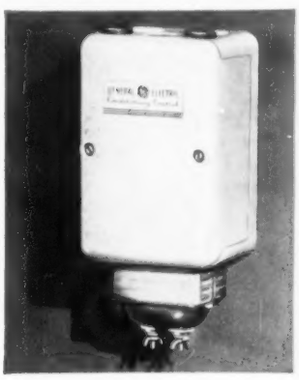
Midget Relay

New midget relay, known as Bulletin 105, is designed for use on either a.c. or d.c., is available with contacts arranged for single-pole, normally open, normally closed or double-throw. Relay is rated to handle approximately one horsepower and is furnished with coils for operation on standard voltages, either a.c. or d.c. up to 110/115 volts at standard frequencies. On 220/230 volts, coils can be supplied for not less than 50 cycles. With overall Bakelite base dimensions of $2\frac{5}{8}$" × $1\frac{7}{8}$" and an overall depth of $1\frac{1}{2}$", new relay can be mounted in the familiar wall type push button box.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*



Magnetic Relay with Control Transformers

New "CR 7865-C2" magnetic relay with control transformer has been designed for summer-winter control of boilers, control of power apparatus on cooling systems in con-



junction with room thermostat, operation of two oil burners from a single instrument, application of power to unit heaters and unit coolers at direction of low-voltage thermostat, etc. Consist of enclosed relay and low-voltage-transformer units used as relaying means between low-voltage thermostats, limit switches, or other low-voltage controls and line-voltage loads such as motors. The relay is a d-p. d-t. form. When it is used with a 3-wire low-voltage device, one pole is used as a holding circuit, hence only one pole is available for a power circuit. Transformer supplies low-voltage energy to relay circuit.—*General Electric Co., Schenectady, N. Y.*

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A MESSAGE TO AMERICAN INDUSTRY BY

LEWIS B. SWIFT—President of Taylor Instrument Companies, Rochester, N. Y., Toronto, Canada, and London, England—producers of thousands of different scientific instruments. Engineer head of an organization which designs, makes and installs control systems for every major industry in the United States.

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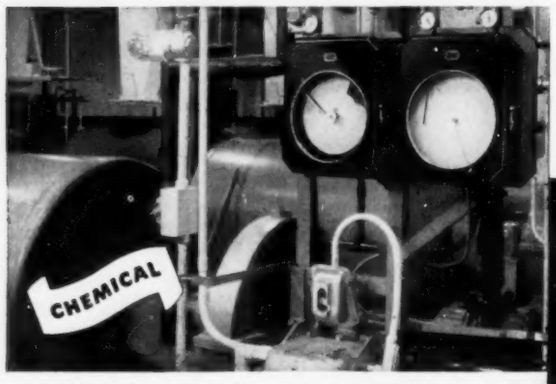
"Speed up! Speed up! is today's plea to Industry.

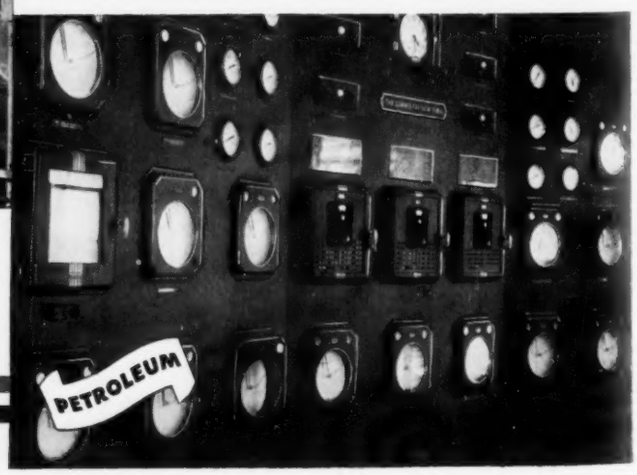
"*Speed up*, so that this country can produce *now* all that we need *now*, making America's preparedness a fact, not just a hope—

"*Speed up* the steady, smooth operation of every plant and factory from coast to coast—

"*Speed up*, and still produce better things



CHEMICAL—From carefully controlled chemical processes come better cellulose products. Taylor Instruments help *automatically* to provide this careful, constant, precision control of processes which must be *exact*.



PETROLEUM—Delicate processing operations in the oil industry are so exactly controlled by Taylor precision instruments that the resulting product assures maximum top-grade performance under all conditions.

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L. B. SWIFT, *President*, TAYLOR INSTRUMENT COMPANIES

than in quieter times—more uniformly good clothing, food, petroleum products, articles for national defense. And produce many more of them at lower costs!

"*Speed up*, without sacrificing the safety of men or machines.

"*Speed up*, without putting too heavy a burden on personnel or payroll.

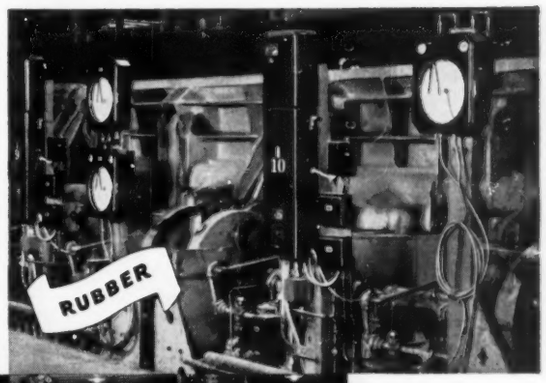
"Taylor is ready to help *you* speed up. Taylor Precision Control of temperature, pressure, flow, and liquid level will help you modernize your plant. Taylor's indicating, recording, and controlling instruments will help *automatically* to insure efficient operation in a new plant. Taylor will give you the one right instrument you need for one part of one operation—or the one complete and correct control *system* for your whole production process.

"For nearly ninety years, helping to *speed up* Industry has been Taylor's biggest job. It never was a more important job than right this very minute. That's why Taylor Instrument Companies have speeded up their own production. That's why you must. *You* must be prepared, because *America must be prepared!*"

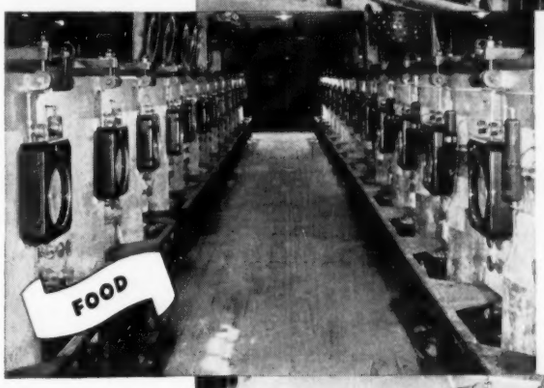
J. R. Swift

PRESIDENT

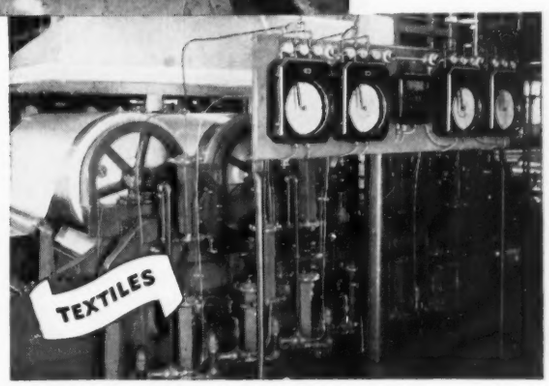
Taylor Instrument Companies, Rochester, N. Y.
Toronto, Canada, and London, England



RUBBER—No matter how great the speed in the processing of rubber — nature's or man's—Taylor Instruments *automatically* help to guarantee lasting strength.



FOOD—In food processing, controlling temperatures and pressures with Taylor Instruments helps to insure constantly uniform high quality.



TEXTILES—In this vital industry, the Taylor engineered slasher control system *automatically* records and controls temperatures. Finer cloth is thus made faster.

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Indicating / Recording · Controlling

TEMPERATURE, PRESSURE, FLOW
and **LEVEL INSTRUMENTS**

Intelligence and Instruments*

By L. W. WALLACE

Director of Engineering and Research, Crane Co., Chicago, Illinois

THROUGHOUT the history of man there have been present both intelligence and instruments of some form and value. There are records which indicate that at times a high order of intelligence prevailed, and that instruments, though crude in comparison with those of more modern times, were used to good effect. It also is true that there are records to show that the reverse conditions prevailed at times. To find evidences of both good and bad, one does not necessarily have to resort to ancient history. Perhaps we would not have to go far in point of either time or place to find the results of a low order of intelligence or the effects of using instruments of "bad odor." Indeed we may find such evidence too near for comfort. It is such conditions which give us concern and are the reason why we are here.

The combination of a high order of intelligence and excellent instruments gives no concern. There are too many cases of excellent performance to justify the raising of any question when it is known that such a combination prevails. But a couple consisting of either a low order of intelligence and good instruments, or good intelligence and poor instruments, is to be watched. It is profitable of course to divorce such couples as soon as it is known that they are present. The more dangerous couple of the two, in most if not all instances, is that of a low order of intelligence and good instruments. If there is present a high order of intelligence, satisfactory results may be obtained with less than good instruments, but the reverse is not true. There are other possible couples with variations of degree of competency and reliability of the two factors involved.

For the sake of further analysis, assume that the instrument to be used is well adapted for the purpose at hand and that mechanically it will stand the gaff. Some may conclude that the job will be well done. In all but the most simple situations—which type of situation is not playing any part in the present discussion—such a conclusion is fallacious and may result in great economic loss or property damage or both.

In many important situations, regardless of how excellent the instrumentation may be, there is no substitute for human intelligence. Let us take a look at some questions which arise.

1. Is the operator infallible as to (a) the application of the instrument; and (b) as to its operation? There are many situations where the correct application and operation are of the first order of importance. In such cases either improper application or operation may invalidate the value of all data collected regardless of the merits of the instrument. Unless the operator is fully aware that such is true and painstakingly obtains the required type of application and operation, all will be lost.

2. Is the operator infallible with respect to the conditions to which he subjects the instrument? If he is, then he will be thoroughly informed as to the design, purpose, operation, care required and the limitations of the instrument, and he will not mistreat it with regard to any of these factors. To violate any of them means jeopardizing the reliability of the results obtained.

3. Is the operator infallible as to the program in regard to such factors as: (a) frequency and character of readings; (b) the number of readings to be taken in order to obtain the necessary body of data; (c) the quality of readings—is it a case where tolerances may be very limited or reasonably so? In my judgment there is no more difficult nor important function of an operator than program making. It is in many cases far more important than the selection of the instrument to be used. Perhaps in no other one regard is more time and effort wasted than in unintelligent program making. There is certainly no substitute for a high order of intelligence with regard to this matter.

4. Is the operator infallible in the analysis of the data obtained and the deductions made therefrom? This of course concerns the end result sought from the very beginning. If the analyses and deductions are faulty, then the entire effort has been a failure. A quotation from Lord Kelvin seems appropriate here. He said, "Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than looking for something new. Yet nearly all the grandest discoveries of science have been but the rewards of accurate measurement, long-continued labor in the minute sifting of numerical results."

Lord Kelvin recognized the great value of accurate measurement, but the emphasis placed upon the long-continued labor in the minute sifting of numerical results is to be noted. If the operator be of the type referred to by Lord Kelvin as having a non-scientific imagination, then again full value will not be realized from the effort because there will not occur the requisite minute sifting of numerical results. It has been my observation that it is rather difficult to obtain that minute sifting desired. In many cases there is a certain amount of exhilaration in collecting data but less in determining what story they tell.

Consequently it is usually much more difficult to get the intellectual, analytical job done well than it is the mechanical one of collecting the data. Here again the instrument, however excellent it may be, is not all of the answer nor the major part of it in many cases.

5. Is the operator infallible, again quoting Lord Kelvin, to "the shady, doubtful distinctions between truth, half-truth, whole-falsehood? In the laboratory everything tested or tried is found true or not." Instruments may tell the whole truth, a half-truth or a falsehood. They are not infallible. They are not always 100 percent accurate. It requires human intelligence to determine their degree of infallibility and make appropriate allowances for it.

6. Does the operator recognize and allow due weight not only for his own fallibility, but also for those associated with him and for the instruments used? A weighing of these factors is essential if the end results are to be as required.

Perhaps other questions could be stated relating to the infallibility of the operator. However, those given are sufficient, it seems to me, to make a case in favor of the intelligence factor in any situation involving measurement. The mere statement of the questions should be sufficient regardless of how adequate the answers may be.

I am quite confident that we here recognize the import and significance of such questions; and the moment each was stated the answer instantly appeared in your mind.

I have endeavored not to labor the issues, but all the questions stated comprise a part of my experience, which I feel sure has been a part of yours. In this regard my experience has covered a rather wide range of activities, including production control and research.

You will recall that the questions concerning the operator were based upon the premise that there was no question as to the excellence of the instrument within and of itself. This premise relieved the operator of the function and responsibility of selecting the instrument, which within itself involves knowledge and judgment.

It will be readily appreciated, of course, that if the correct instrument were not selected then all the hazards which rest in the operator would probably be magnified.

It is axiomatic that any job worth doing at all is worth doing well. It likewise seems axiomatic to me that in all cases nothing less than the requisite quality of intellect and instrumentation is the only road to satisfactory accomplish-

*Presented at the June 6, 1940, dinner meeting of the Chicago Instrument Society.

ment. The one who skimps on either or both is deluding himself and will surely meet with disappointment.

The discussion thus far has been in terms of mechanical instruments and the human factor. It is my feeling that neither business nor industry has utilized to the fullest possible degree mathematical and statistical *methods*, if you please, as instruments. There is far more to be obtained from these methods than most of us realize. I feel confident that we shall use these methods a great deal more in the future than now. They will supplement and complement the instrumentation now in vogue. It is obvious that they will require a high order of intelligence, in some respects perhaps even higher than that now found in most companies. Men of such training will certainly approach the solution of many problems on a sounder basis of logic than is often the case now. They will be stamped, in all probability, with a lesser degree of fallibility than is sometimes found among operators.

Instruments in the sense we know and use them are not old in terms of hundreds of years. In fact, instruments of precision, refinement and control are not over one hundred years old. Many of course are of recent vintage and almost daily improvements and additions are being made. They within themselves represent the application of a great deal of hard thinking, years of accumulated experience and commendable foresight.

Let us examine briefly the background of modern instruments as disclosed in the life and work of one man, who was born on June 26, 1824, slightly over one hundred years ago. I refer to William Thomson, who became Lord Kelvin. I have selected him as an example because he represents in a marked degree what results from a combination of brain power, an inquisitive mind, an inventive ability and practical common sense. His life story is a complete answer to many questions relative to intelligence and instruments.

It has been said of Lord Kelvin that "his precocity was remarkable." We are ready to believe this in the light of the following condensed record.

At the age of ten he entered Glasgow University. At the age of thirteen he took the College prizes in Mathematics, Natural Philosophy and in Logic, and at the age of twenty became head of the Department of Natural Philosophy at Glasgow University, in which capacity he served more than fifty years.

He established there the first experimental laboratory wherein students could obtain practical experience. He may be said to have been the first to combine intellectual capacity in the sciences with experimentation and instrumentation or with what we know today as applied physics and engineering. Because of this it has been said of him, "Never was so great a physicist, so great an engineer."

The marriage, through Lord Kelvin, of intellectuality, experimentation and instrumentation, among numerous accomplishments, gave to the world the following:

An established Second Law of Thermodynamics;

The absolute scale of temperature and mathematical formulæ whereby this could be compared with the temperature given by a gas thermometer;

Proof that electrical oscillations are set up when a charged electric condenser is discharged, which is the basis of all methods used for tuning in wireless telegraphy and broadcasting.

The foregoing list could be materially extended.

In such work in fundamental science and in the establishment of basic principles, Lord Kelvin early recognized the absolute need for experimentation and accurate measurement. As a consequence he and those trained by him are responsible for a long list of instruments used for many purposes. Among them are: electrometers, voltmeters, mirror galvanometers, tide predicting machine, gyroscopes, marine compass and many others.

I have used several quotations from Lord Kelvin. Permit me to cite some more in order that you may refresh your memory as to his philosophy. Said he:

"Science is bound by the everlasting law of honor to face fearlessly every problem which can fairly be presented to it."

And again:

"When you call a thing mysterious, all that it means is that you don't understand it."

It has been said of him: "No one was more punctilious in working out the mathematics of a subject and obtaining numerical expressions which could be compared with the results of experiment."

In view of the foregoing, what would be the answer of Lord Kelvin to a question concerning intelligence and instruments? Can there be any doubt that his answer would be that they complement and supplement each other. Either alone is not sufficient; both are required if the total answer is to be obtained.

I have given the time I have to Lord Kelvin because it seems to me that his approach and methods exemplify the very thing we are striving to realize. Furthermore, his contributions to the world of science and engineering are proof sufficient that the intelligent use of instruments begets results of extreme value, consistency and accuracy. On those occasions when you feel the need for mental refreshment and an increase in courage, turn to the life and works of Lord Kelvin. It may be well on occasion to make a like recommendation to the men in the front office.

We have been speaking in terms of available instruments and have said nothing about existing gaps. There are gaps. There are fields badly needing entirely new instruments or a logical adaptation of existing ones. Only recently several such cases have come to my attention.

Rubber is a material being used in an increasing amount and for new purposes. It is my feeling that we have not used rubber to the degree which it would be advisable in terms of its mechanical properties. Its use is being retarded because apparently there are no methods of control which give both the manufacturer and the user positive assurance that a rubber of definite characteristics and performance can be obtained from day to day. There appears to be no definite means of testing rubber whereby the user can determine positively that successive lots meet his specifications of purchase.

There is a great need for recording electrical resistance strain gages. These would be most useful in the field of transportation.

A prominent authority in the power plant field recently expressed the need for a low-cost instrument for showing the thermal efficiency of industrial furnaces.

There has been expressed a need for the design and construction of a fatigue machine capable of testing full-size elliptical springs.

A thermocouple for high velocity is required.

There is being developed a high-speed camera to be used with an oscillograph and stroboscope to analyze motion.

Means of detecting and measuring stresses in inaccessible parts due to vibrations, such as in fillets and in the bearing sections of crankshafts and the like.

It has been suggested that an investigation should be made of the control equipment for high-pressure wells.

Production of a satisfactory steam flow meter to record more accurately rates of flow over a wider range.

There is need in the oil industry for proper metering of both refined products and the crude oil itself.

Develop a calculating machine to reproduce the properties of steam such as available energy, volume and other factors.

The foregoing are typical examples taken from a longer list of required additional instruments of measurement. The list certainly indicates a widespread appreciation of instruments and also that all of our Lord Kelvins have a sizable job before them.

The subject we have been considering is an extremely important one. Its importance warrants the expenditure of the effort and time which can be placed upon it, both from the point of view of intelligent development and use of instruments of control and measurement. A higher degree of coördination of effort and exchange of information and experience than now obtains is highly desirable and would be most beneficial to all concerned. You are to be commended for endeavoring to bring about such an improved state of affairs.

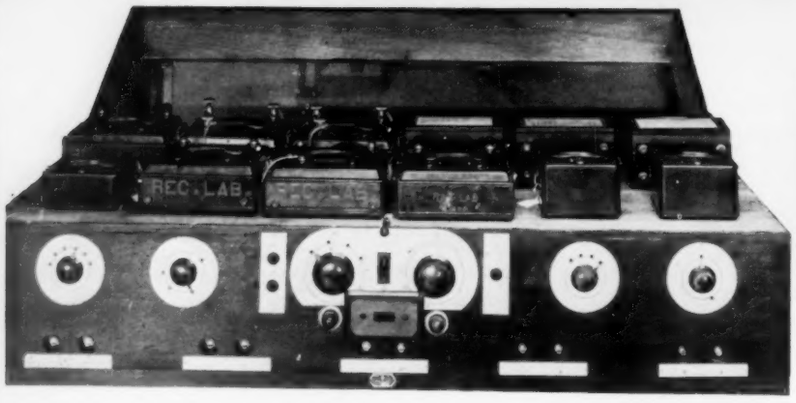

Fig. 1. The easily-assembled calibrator for electrical instruments. Cover opened to show the twelve laboratory standards.

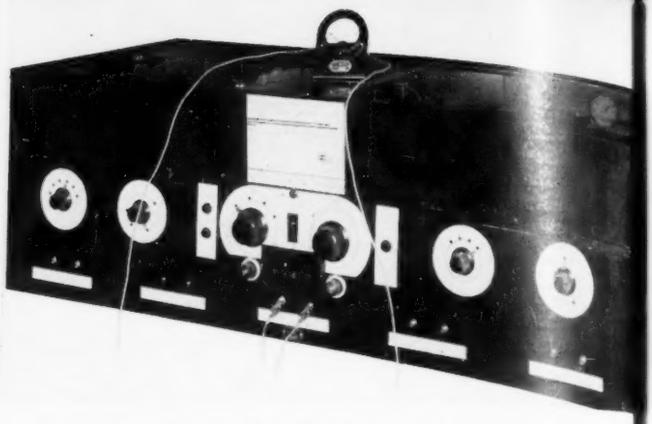

Fig. 2. The easily-assembled calibrator in use: standards are observed through glass cover.

An Electrical-instrument Calibrator

By LESLIE E. KULBERG
Boston, Mass.*

IN laboratories where various set-ups are constantly being made, and where varying numbers of instruments are required, it is most convenient to use miniature instruments of the 3½" size. This also applies to the Test Department. In both cases, the small size and low cost of miniature instruments make them convenient.

How are we to check the calibration of the myriad ranges of all the small instruments we are likely to possess?

Every laboratory has an assortment of the larger precision instruments having an accuracy generally within 0.5%. If we have a means whereby we can easily check our small instruments, the larger ones will rarely be needed and a portion of them can be set aside permanently as standards. For greatest convenience, this implies the presence of power supplies and flexible switching circuits.

Fig. 1 suggests one solution to the problem. A glass-topped wooden case contains twelve standard instruments on a shelf, with controls and power supplies on the panel and beneath the shelf. By placing an instrument whose accuracy is to be determined on the plate glass near its standard (which is below the glass), it can be checked over any of the following ranges:

1 milliampere to 6 amperes, d.c.
50 milliamperes to 5 amperes, a.c.
15 to 1500 volts, d.c.
6 to 150 volts, a.c.

The a-c. ranges, although powered by a 60-cycle supply (or 25 cycle, as the case may be) can also be used for radio-frequency instruments.

Fig. 2 shows the arrangement of the instruments on the shelf, their leads extending through holes in it to the base compartment. The top is hinged for easy availability of a standard instrument, should one be needed elsewhere.

For the schematic diagram, see Fig. 3. While it is not claimed to be the best or only manner of attacking the problem, it did make use of various instruments available, and it serves its purpose. (After describing the one actually constructed, some remarks will be made concerning possible variations.)

Both a-c. and d-c. supplies are required. Because it is assumed that switches will be placed in these two circuits externally to the calibrator itself, pilot lights are provided to enable the operator to determine whether the power is on. A d-p.-d-t. Switch (S-1) selects the desired supply and connects it to the remainder of the device. Following S-1 appears the main On-Off Switch S-2 and Pilot Light L-3. When S-2 is on, the Function Switch S-3 determines which of the following circuits is to be energized:

Position 1 permits a.c. or d.c. to be fed into the milliammeter circuits shown above and to the left of S-3 in the schematic diagram. The voltage across the divider R-1, R-2, R-3, R-18 is adjusted by R-18 on the panel to a value suited to the standard instrument (M-3 to M-8) selected by Switch S-4. The instrument to be checked is placed across the milliampere terminals (MA), thereby being in series with its standard.

Position 2 of S-3 selects the ammeter standardizing circuit. Alternating current only is used, being chosen by throwing S-1 into its lower position. Transformer T-1 is thereby energized, supplying either the a-c. standard M-2 directly; or the d-c. instrument M-1, through the copper oxide rectifier RX-1. In either case, the instrument which is to be checked is placed across the appropriate pair of ammeter binding posts, and the amount of deflection adjusted by R-5 or R-6. R-6 appears in Fig. 1 on the right end of the case, while R-5 is at the other end.

When Switch S-3 is on Position 3, with S-1 in the d-c. position and S-8 on 1, a low range d-c. voltmeter M-9 has impressed across it a voltage determined by the divider R-13, when S-6 is in its lower position. *If S-6 is not pressed, a high current will flow through a path through the transformer T-2, and burn out R-21, were it not for fuse F-15.* Therefore, in assembling a calibrator similar to this, it is important not only to remember to include F-15 (and a supply of spares) but also to select its rating with care and foresight. It should "blow" at, or slightly above, the rating of the resistance wire in R-21 which has the highest rating. R-21 is a "tapered" resistor, wound with different sizes of wire for different portions of its rotation, so choose a fuse rating to correspond to the largest wire used in the particular type and make of resistor you select for your R-21. Be sure to place fuse F-15 on the front panel or other accessible location: it may have to be replaced frequently if the operating instructions are not followed.

The instrument used is of the double-range type, explaining why M-9 appears twice.

In the final setting of S-3, namely position 4, other voltmeter ranges, both a.c. and d.c., are provided. M-10 and M-11 are a-c. instruments. With S-8 on its second tap, R-13 determines the voltage across M-10. For higher a-c. ranges, M-11 provides two, 0-75 and 0-150 volts. Taps 3 and 4 respectively of S-8 provide them. R-13 requires adjustment in these cases also. For the 150-volt range, only, switch S-5 must be operated, which throws the auto-transformer T-2 into the circuit to step up the 110-volt supply. The voltmeter to be calibrated connects across the "15 volts d.c., all a-c. volts" binding posts in the above cases.

For d-c. voltage ranges higher than the 110-volt supply, a voltage doubler rectifier is provided. Naturally, an a-c. supply is used for d-c. voltmeter ranges in position 4 of S-3, in order to energize the transformers. T-4 heats the filaments of the Type 81 rectifiers V-1 and V-2, while T-3 provides the plate power. This transformer has a 220-volt

*The author designed this calibrator while in charge of a laboratory of a company which prefers to remain anonymous.—EDITOR.

PARTS LIST

C-1, C-2, C-3, C-4 — 4.5 or 5 mf. 1000 V. Oil-filled Capacitors, or equivalent

F-1 Littelfuse, F-2 Littelfuse, F-3 Littelfuse, F-4 Littelfuse, F-5 Littelfuse — Size is determined by range and make of instruments to be protected.

F-6 Littelfuse, F-7 Littelfuse, F-8 Littelfuse, F-9 Littelfuse, F-10 Littelfuse, F-11 Littelfuse, F-12 Littelfuse, F-13 Littelfuse — Size is determined by range and make of instruments to be protected.

F-14 10-amp. Littelfuse

F-15 (See Text.)

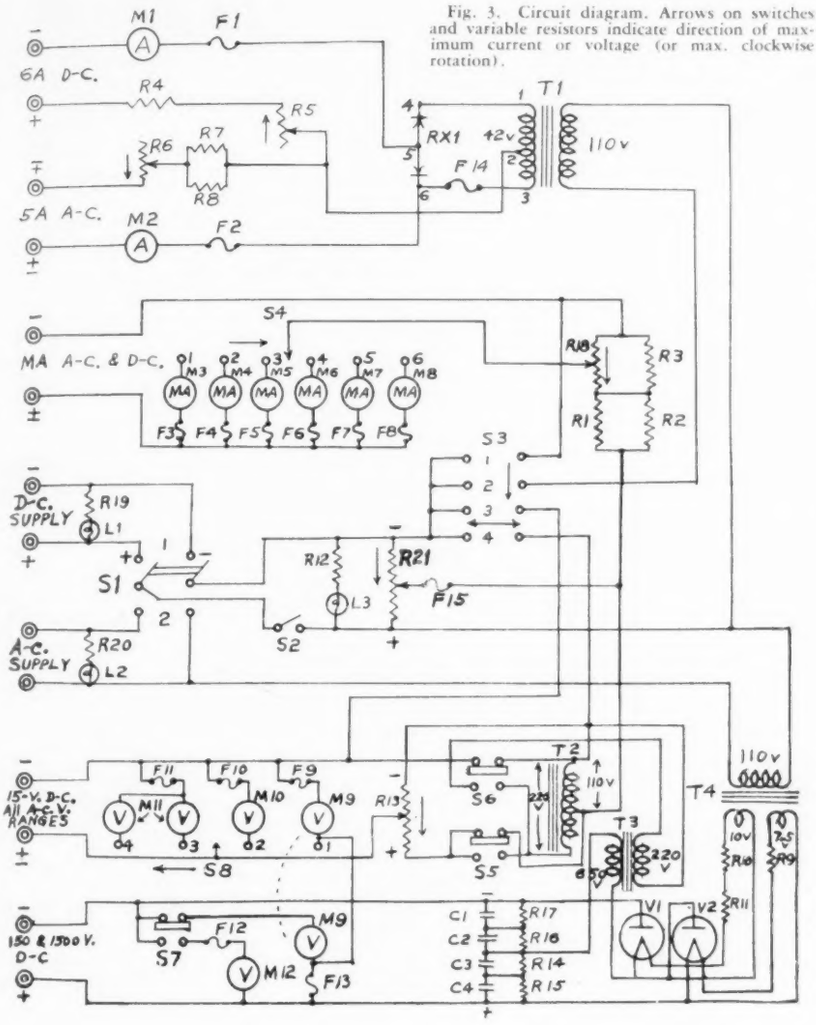

Fig. 3. Circuit diagram. Arrows on switches and variable resistors indicate direction of maximum current or voltage (or max. clockwise rotation).

L-1 d.c. Supply Indicating Lamp, 18 V.
L-2 a.c. Supply Indicating Lamp, 18 V.
L-3 On-Off Supply Lamp Stromberg-Carlson No. 18A
M-1 0-6 amp. d-c. Standard
M-2 0-5 amp. a-c. Standard
M-3 0-1000 milliamp. d-c. Standard
M-4 0-20 milliamp. d-c. Standard
M-5 0-100 milliamp. d-c. Standard
M-6 0-500 milliamp. d-c. Standard
M-7 0-50 milliamp. a-c. Standard
M-8 0-500 milliamp. a-c. Standard
M-9 0-15-150 volt d-c. Standard
M-10 0-6 volt a-c. Standard
M-11 0-75-150 volt a-c. Standard
M-12 0-1500 volt d-c. Standard
R-1 350 ohms
R-2 350 ohms
R-3 100 ohms
R-4 0.3 ohms
R-5 12 ohms 5-amp. Slide Wire Rheostat
R-6 12 ohms 5-amp. Slide Wire Rheostat
R-7 5 ohms
R-8 5 ohms
R-9 0.625 ohms
R-10 1.4 ohms
R-11 1 ohm
R-12 2000 ohms
R-13 2500 ohms 25-watt General Radio Potentiometer
R-14 1 megohm
R-15 1 megohm
R-16 1 megohm
R-17 1 megohm
R-18 900 ohms 25-watt General Radio Potentiometer
R-19 1200 ohms Westinghouse S#790152 or 846354 Lamp Resistor with Socket
R-20 1200 ohms Westinghouse S#790152 or 846354 Lamp Resistor with Socket
R-21 Special Voltage Control Potentiometer Ohmite Model L, Type 15X, 500 ohms, tapered to carry 0.36 ampere constantly and up to 1.25 amperes momentarily through last few turns of full clockwise rotation, for use while in semi-closed box.
RX-1 Copper Oxide Rectifier (Removed from Westinghouse S#596102 6 amp. battery charger)
S-1 A-c. - d-c. Switch
S-2 On-Off Toggle Switch
S-3 Function Switch
S-4 Milliammeter Selector Switch
S-5 110-220 Volt Selector Switch
S-6 Instrument Circuit Opening Switch
S-7 150-1500 Volt Selector Switch
S-8 Voltmeter Selector Switch
T-1 Charger Transformer (Removed from the same battery charger as RX-1 above)
T-2 Auto Transformer
T-3 Plate Transformer
T-4 Filament Transformer
V-1 Type 81 Rectifier Tube
V-2 Type 81 Rectifier Tube

primary (and requires use of S-6 to supply the correct input voltage) merely because it happened to be available. A 110-volt primary is preferable. Manipulation of switch S-6 provides the low range of M-9, while S-7 must also be pushed simultaneously, to provide the higher range. The 150-volt and 1500-volt d-c. terminals accommodate the instrument to be checked.

In the foregoing, the potentiometer R-21 has been mentioned but briefly. In actual operation, it is the most important control of the entire calibrator. Where mention has been made of adjusting R-18 in the milliammeter section or R-13 in that of the voltmeters, they have been set at certain definite positions (determined by trial) which are marked on the indicator strips around the knobs, and the final adjustment made with the aid of R-21. It must be used with the voltage doubler rectifier, being the only adjustment provided. Only in the case of the a-c. and d-c. ammeters is it not used. In the calibrator described it was provided with a helical spring which always tends to place it in the zero voltage position when not in use. The idea was to prevent some person unfamiliar with the device from burning out instruments by snapping on the main switch when R-21 was turned on too far for the particular range to be calibrated. If this danger is absent, it is preferable to dispense with the spring.

There may be some question as to the effect of ripple from the rectifiers on the accuracy of d-c. instruments, especially since no filters are provided. Almost without exception d'Arsonval movements are used to-day. If both the standard and doubtful movements are alike, there is no question present, but should an iron vane movement be checked against a d'Arsonval movement, the accuracy would be affected. In the usual case of moving-coil movements, no filtering of the rectifiers is necessary.

All standard instruments are fused, making it impossible to damage them by overloads.

PHYSICAL DETAILS

The equipment is housed in a box 46″ × 18″ × 14½″ overall. From the shelf to the glass, a height of 5″ is provided inside for the standards; and 7″ is the equivalent dimension below decks for the power equipment.

The panel, Fig. 2, has affixed to it inexpensive indicating strips of Bristol board. After labeling them with India ink, they were given two coats of clear lacquer to prevent their being soiled. The five pairs of binding posts are slotted to provide easy attachment for clip leads from the instrument to be tested. In addition, they are recessed, for the sake of safety. *(Concluded on page 197)*

Correlation between Hardness and the Magnetic Properties of Solid Matter

By S. R. WILLIAMS
Professor of Physics, Amherst College

HARDNESS AS MEASURED BY MAGNETIC METHODS

It has been a common idea for a century or more that the magnetic properties of magnets are greatly influenced by the mechanical hardness of the steel from which the magnets are made. This is illustrated by the following references: In 1844 William Scoresby[1] published the results of some of his magnetic researches in a book of two volumes entitled "Magnetical Investigations." The author devoted a large part of his first volume to the effects of hardness on the magnetic powers of the magnets which he had constructed. A final summary of this first volume is, "That the degree of retentiveness of magnets is directly as the hardness, and inversely as the energy." Again he says, "Hardness, therefore, becomes most essentially important for resisting the effects of unfavorable magnetic action, whether arising from the earth's magnetism operating against that of the magnet, or from unfavorable contacts with, or proximity to another magnet." In other words it may be inferred from Scoresby's work that the retentiveness of his magnets was a measure of their hardness.

Elsewhere Thompson[2] emphasizes a similar point of view by saying that "In the preparation of permanent magnets temper is almost as important a consideration as the chemical composition of the material."

Cheesman[3] has made some interesting observations on the influence of mechanical hardness on the magnetic properties of steel and iron. He came to the conclusion from his research that hardness induced by cold working is quite distinct from that produced by heat treatments.

Joule[4] in his original discovery of the magnetostrictive effect which bears his name says, "On inspecting the tables, it will be remarked that the elongation is, for the same magnetic intensity, greater in proportion to the softness of the metal. It is greatest of all in the well annealed iron bars, and least in the hardened."

In a study of the changes in length which iron rods undergo when magnetized longitudinally, Bidwell[5] comes to the conclusion: "It appears, therefore, that as regards magnetic changes of dimensions an iron rod or ring is affected by annealing in very nearly the same manner as by tensile strength, a result which would hardly have been anticipated."

The author has been interested for more than thirty years in magnetic phenomena, particularly in that field known as magnetostrictive effects, those effects in which certain solid bodies, such as iron, nickel, cobalt, manganese and their alloys show comparatively large changes in dimensions when subjected to magnetizing forces. Over and over again one is confronted in this type of research by the fact foreshadowed in the pioneer work of Joule that hardness and changes in length due to a magnetic field have a vital correlation. In the past we have spoken of hardness as the agent controlling magnetic phenomena. Perhaps a better approach to this interrelation between magnetic phenomena and hardness is to say that some more basic or fundamental effect controls simultaneously the magnetic and mechanical characteristics of matter in the universe, causing them to vary at one and the same time, rather than to say that one is the cause of the other.

Be that as it may, one is able to draw the general conclusion: There is one and only one set of physical and chemical properties corresponding to a given set of magnetic characteristics, and, conversely, there is one and only one set of magnetic properties corresponding to a given set of physical and chemical characteristics.[6]

In the field of Metrology, or the Science of Measurements, it is a well understood principle that we measure one physical magnitude in terms of some other physical magnitude, and this goes on until we find ourselves measuring all physical magnitudes in terms of the units of Length, Mass, and Time, which are our Fundamental Units for all physical magnitudes. For example, we measure an electric current in terms of the force which its magnetic field exerts on a unit magnetic pole; we measure the index of refraction by the amount of deviation which a ray of light undergoes when passing obliquely through the bounding surface between two media. The moment we establish a relation between two physical magnitudes, that moment are we in a position to measure one physical magnitude in terms of another. Sufficient evidence has already been adduced to show that since hardness is so vitally associated with the magnetic properties of a solid, whether as a cause or as a concomitant phenomenon, we are afforded an opportunity to attempt the measurement of hardness of solids by their magnetic characteristics.

This point of view will form the main theme of succeeding pages and accounts for what has gone before—a humble attempt of an enquirer to find, if possible, some better understanding of the physical property we call "hardness of solids," and at the same time arrive at a clearer concept of magnetic phenomena. Thirty-five years ago magnetism seemed a hopeless subject of study, because so many factors were involved. Not a few at that time were saying, "why investigate magnetic phenomena when they are so complicated?" There were others with a different point of view.

Building on the labors of Oersted, Faraday and Rowland, the Barnetts[7], the two Comptons[8], Richardson[9],

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[1]W. Scoresby. Magnetical Investigations. Vol. 1, pages 361-364. 1844. Longman, Brown, Green and Longmans, London. Two volumes.

[2]S. P. Thompson. The Electromagnet. Pages 386-394. E. and F. N. Spon, London, 1892, 452 pages.

[3]L. M. Cheesman. Eber den Einfluss der mechanischen Harte auf die magnetishchen Eigenschaftern des Stahles und des Eisens. *Wiedemann's Annalen*, Vol. 15, 1882, pages 204-224. A Correction: Vol. 16, 1883, page 712.

[4]J. P. Joule. On the Effects of Magnetism upon the Dimensions of Iron and Steel Bars. *Philosophical Magazine and Journal of Science*, Vol. 30, 1847, pages 76-87 and 225-241.

[5]S. Bidwell. On the Effect of Magnetisation upon the Dimensions of Wires and Rings of annealed Iron. *Proceedings Royal Society*, Vol. 55, 1894, pages 228-234; and Vol. 56, 1894, pages 94-99.

[6]S. R. Williams. Magnetic Phenomena. Page XVII. McGraw-Hill Book Co., New York and London, 1931. 230 pages.

[7]S. J. Barnett & L. J. H. Barnett. New Researches on the Magnetization of ferromagnetic Substances by Rotation and the Nature of the Elementary Magnet. *Proceedings of the American Academy of Arts and Sciences*, Vol. 60, 1923, pages 127-216.

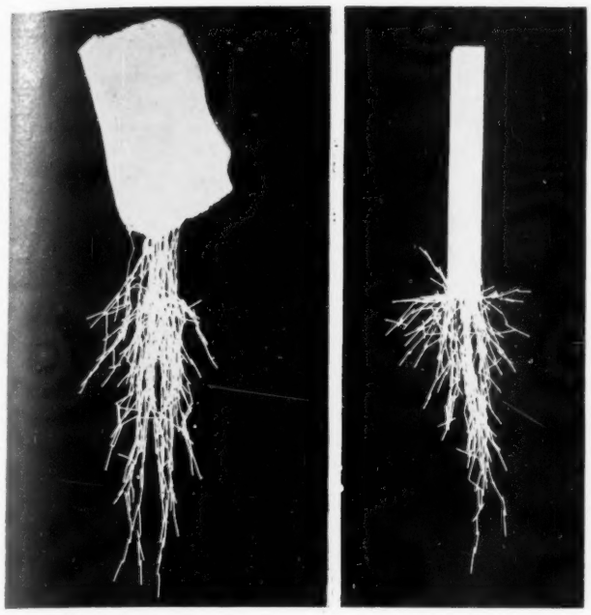
[8]K. T. Compton & E. A. Trousdale. The Nature of the Ultimate Magnetic Particle. *Physical Review*, Vol. 5, 1915, pages 315-318.

A. H. Compton and O. Rognley. The Nature of the Ultimate Magnetic Particle. *Science*, Vol. 46, 1917, pages 415-416.

See Also *Physical Review*, Vol. 16, 1920, pages 464-476.

[9]O. W. Richardson. A Mechanical Effect accompanying Magnetization. *Physical Review*, Vol. 26, 1908, pages 248-253.

A. P. Chattock & L. F. Bates. On the Richardson Gyro-magnetic Effect. *Philosophical Transactions of the Royal Society*, Vol. 223, 1922-23, pages 257-288.



(a) (b)

Fig. 263. (a) A piece of magnetite attracts small pieces of iron wire to itself and holds them in suspension. It is called a natural magnet. The small pieces of iron consist of short sections of iron wire. (b) A piece of steel rubbed with a piece of magnetite will behave as did the magnetite. Such a piece of steel is called an artificial magnet.

Kapitza[10], Becker[11], Stoner[12], and Bitter[13] have opened up this field of research so that there begin to emerge emerge vistas of a unified view of magnetic phenomena. Likewise the difficulties involved in studying hardness should not be a deterrent to honest study and further endeavors to formulate a unified picture of what hardness is.

In preceding chapters an attempt was made to explain and define, as far as possible, the terminology used in describing hardness and the methods for its measurement. If hardness is to be measured by magnetic methods it is essential, for a better understanding of the process, to digress a bit and explain certain fundamental aspects of the phenomena of magnetism.

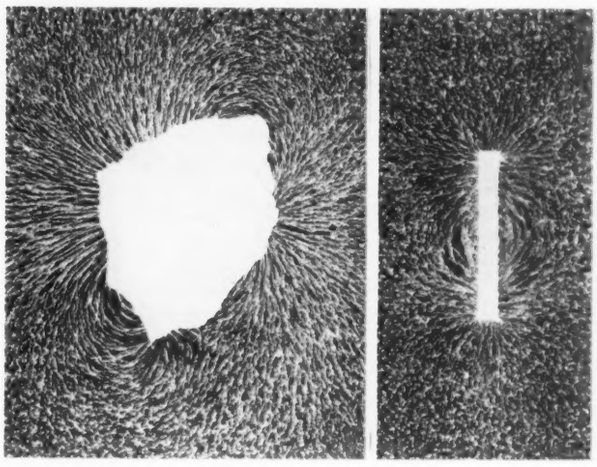
MAGNETIC PHENOMENA

Our earliest knowledge concerning magnetism (about 600 B.C.) consisted in the fact that certain rocks or minerals possessed the power of attracting small bits of iron and holding them in contact with the mineral. The commonest substance to show this property is an oxide of iron, FeO, Fe_2O_3, known as magnetite. See Fig. 263(a). Following this it was observed that if an elongated piece of this oxide of iron was suspended by a fine fiber, with the major axis in a horizontal position, it would turn into a north-south position. Such a body was called a lodestone (or leading stone). The end toward the north is called the north-seeking or positive pole of the direction-giving stone and the end toward the south is called the south-seeking or negative pole.

Two positive (like) poles repel each other and unlike poles attract each other with forces which Coulomb found to be directly proportional to the product of the two pole strengths and inversely as the square of the distance between the centers of the poles. This may be expressed by the defining equation

$$\text{Force} = m_1 m_2 \mu d^2 \qquad \text{(Coulomb's Equation)}$$

in which m_1 and m_2 are the respective pole strengths, d the distance between centers and μ a factor of proportionality whose value is a function of the medium surrounding the poles. When the poles are immersed in a vacuum, μ is assumed to be unity. Coulomb's equation is a defining equation because it says that we have a unit pole when such a pole at unit distance from a similar pole exerts a unit force, provided the two poles are surrounded by a vacuum, or $\mu = 1$. Thus a force of one dyne exists between two unit poles where they are separated by a distance of one centimeter and immersed in a vacuum. For those who insist on English units it might be well to point out that all magnetic and electrical units are measured in terms of the metric system and only in terms of the metric system.



(a) (b)

Fig. 254. (a) Magnetic field of a lodestone. (b) Magnetic field of an artificial magnet.

Another step in the development of our knowledge concerning magnetic phenomena was the observation that a rod of iron rubbed with a piece of lodestone acquires the property of attracting small bits of iron to itself—as did the lodestone. See Fig. 263(b). A bar of iron magnetized in this or any other way has all of the functions of the lodestone: it has poles, it sets itself in a north-south direction and thus ushers in our modern compass needles. A body is said to be magnetized when it possesses the power to attract small bits of iron to itself as does the lodestone (magnetite).

Around every natural and artificial magnet there exists a magnetic field. Fig. 264(a) and (b). It exists within that space about the magnet in which magnetic forces may be detected, whose strength of field (magnetizing force or field intensity) possesses magnitude and direction—the earmarks of a vector quantity. The magnitude of the field strength is defined in terms of the force which that field exerts on a unit magnetic pole. In a non-uniform field this value will vary from point to point as is the case in the field surrounding a bar magnet. The direction of a magnetic field is the direction in which a positive magnetic pole would move were it possible to have a positive pole isolated and free to move. The de-

[10]P. Kapitza. The Change of Electrical Conductivity in Strong Magnetic Fields. *Proceedings of the Royal Society*, Vol. 123, 1929, pages 292-372.
[11]R. Becker and W. Doring. Ferromagnetism. Julius Springer, Berlin, 1939. 440 pages.
[12]E. C. Stoner. Magnetism and Matter. Methuen and Co. Ltd., London, 1934. 575 pages.
[13]F. Bitter. Introduction to Ferromagnetism. McGraw-Hill Book Co., New York and London, 1937. 314 pages.

fining equation for the magnetizing force of a magnetic field is:—

$$H = m_2/\mu d^2$$

where m_2, d and μ have the same meaning as in Coulomb's equation.

That magnetic poles cannot be isolated may be demonstrated by the simple experiment of breaking a magnet in two: instead of holding a positive pole in one hand and a negative pole in the other, each hand holds a complete magnet. Suppose one goes on breaking either half in two, there will come eventually an elementary magnet whose subdivision creates neither two magnets nor two poles. Just what is that elementary magnet which cannot thus be subdivided? For the present let us call it the *magneton*.

Coulomb thought of magnetic poles as isolated units reacting upon one another. Inasmuch as it is impossible to isolate a magnetic pole it seems more sensible to deal with di-pole conceptions and say that what one observes in magnetic phenomena are the forces between magnetic fields in which they seek to set themselves parallel to one another. Each point of view leads to the same formulation, but the dipole concept is clearer.

The fact that magnetic fields tend to set themselves parallel to each other leads to the conclusion that when a lodestone or a magnet sets itself in a north-south direction, it is doing so in some other magnetic field. This field, as Gilbert[14] pointed out, is the field of the earth. That is to say, the earth is a great magnet.

[14]W. Gilbert. On the Magnet. Translated by a Committee of the Gilbert Club, C. Whittingham and Co., The Answick Press, 1900. 245 pages.

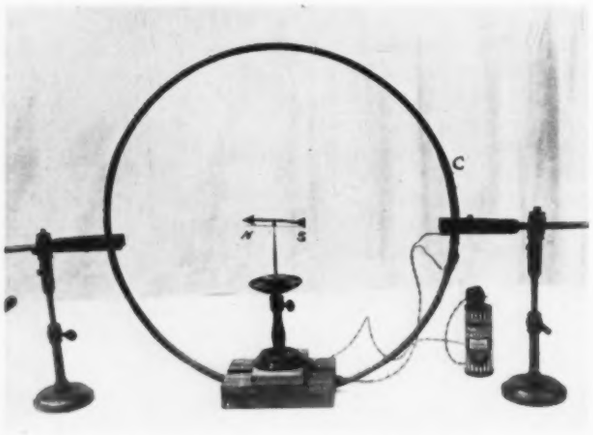


Fig. 266. The large hoop consists of 20 turns of magnet wire. When the current from the dry cell passes through the coil it sets up a magnetic field at right angles to the plane of the coil and the compass needle will turn in that direction. The intensity of the field at the center of the coil is

$$H = 2\pi nI/10R$$

oersteds, where n is the number of turns, R the radius of the coil in centimeters, and I the current in amperes.

What appears as an epochal discovery in our modern theories of magnetism was the one by Oersted[15] who observed that when an electric current flows through a wire a magnetic field is set up about the current so that the field strength at any distance d from the center of the wire is equal to:

$$H = 2I/10d \qquad \text{(Oested's Law.)}$$

where I is the electric current measured in amperes. Fig. 265 shows a cross-sectional view of a wire in which the direction of flow of the electric current is pictured as be-

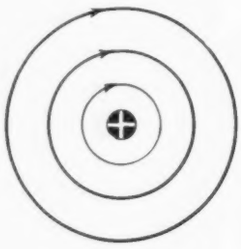


Fig. 265. The dark center is the cross-section of a wire normal to the plane of the page. By convention the electric current flows away from the reader and the direction of the surrounding magnetic field is indicated by the arrows.

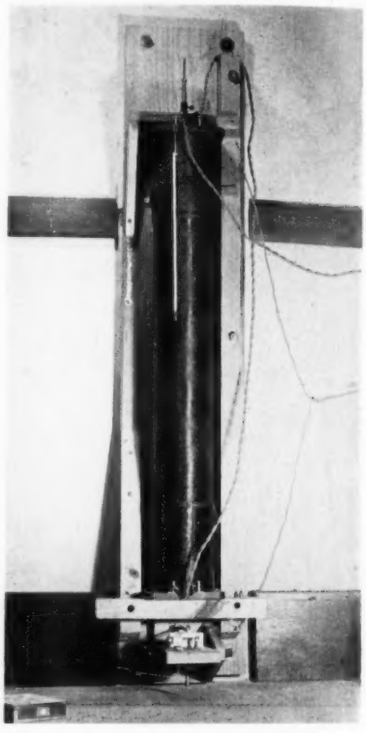


Fig. 267. This coil is one meter long and has about 25000 turns in it of No. 13 double - cotton - covered wire.

ing away from the reader and the direction of the magnetic field is clockwise. The same relation holds between direction of electric current and direction of magnetic field as exists between the forward motion of a right-handed screw and its direction of turning.

If a long, straight wire, for which the last equation holds, is bent into a circle of one or more turns, as in Fig. 266, the magnetic field around each turn of wire unites with those of other turns to give a resultant field through the coil from front to rear when the electric current is flowing in the coil in a clockwise fashion as viewed in Fig. 266. The magnetic field at the center of the coil integrates to

$$H = 2\pi NI/10R \qquad \text{(Eq. of coil)}$$

where I is the current in amperes, N the number of turns in the coil and R the average radius of all the turns. Such a coil becomes useful in building instruments for measuring electric currents (galvanometers, dynamometers, etc.). When such a coil is multiplied side by side into a spiral it becomes a solenoid in which the magnetizing force at the center of a long, slim solenoid is equal to

$$H = 4\pi nI/10R. \qquad \text{(Eq. of solenoid)}$$

In this equation n is the number of turns per unit length, I, the current in amperes and R the average radius of the turns. Such a coil will be used in much of the work to be described later. See Fig. 267.

[15]John Christian Oersted. Experiments on the Effect of a Current of Electricity on the Magnetic Needle. *Annals of Philosophy*, Vol. 16, 1820, pages 273-276.

out of the work of Oersted[15], Faraday[16] and Maxwell[17] there finally arose the idea that electric currents were nothing more than a stream of electric charges and that electricity in motion gave rise to magnetic fields. The modern conception simply specifies that the stream of electric charges which flows in a metallic conductor is a stream of negatrons (negatively charged particles) percolating through a lattice work of atoms in the crystalline structure of the conductor.

There follows from this conception the inevitable conclusion that no magnetic field can exist without electricity in motion. Rowland[18] gave force to this conclusion by spinning a disk charged with static electricity and showing that when static electricity was set in motion mechanically a magnetic field was produced. In a qualitative but spectacular fashion, Wood[19] fired charged gun-shot past a sensitive magnetometer (magnetic needle suspended on a fine fiber) and showed that as the moving charged shot passed the magnetometer needle the latter was slightly deflected by the magnetic field of the moving charged shot.

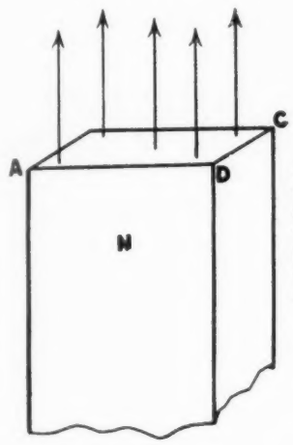


Fig. 268. The area *ABCD* represents one square centimeter and each line a maxwell of flux. Therefore, this is a quantitative representation of a field intensity of five oersteds.

If then magnetic fields are due to moving electric charges, how is it that we find magnetic fields around magnets, both natural and artificial?

The two Compton brothers, by means of X-ray analysis of substances when magnetized and again when unmagnetized, were led to the point of view that when a substance was magnetized it could not be a case of whole atoms or aggregates turning over, but that if anything turned it must be some constituent part of the atom itself. The final conclusion was that the elementary magnet must, therefore, be a negatron, a charged particle, spinning on its own axis like a top or a gyroscope and that, like Rowland's spinning disk with the static charge of electricity, it would show a magnetic field.

The gyroscopic nature of the elementary magnets or magnetons had a confirmation in the now classical experiments of the Barnetts. They rotated cylinders of iron, nickel and cobalt and, though free of all extraneous magnetic fields, these cylinders became magnets due to the fact that the axes of spin of all of the elementary magnets, as all good gyroscopes do, turned in the same direction as the axis of rotation of the cylinder. This gave a distinct polarity to the cylinder as a whole, or, in other words, the cylinders were magnetized by rotation. It follows from this argument that a body is unmagnetized when the axes of spin of the magnetons or gyroscopes sit in random orientation and that it is magnetized when they have a common direction for their axes of spin.

To this picture of the elementary magnets in the atoms, investigators like Bitter[13] and Slater[20] have applied quantum mechanics and made it possible to formulate many of our known magnetic phenomena, and advance greatly our knowledge of the physics of metals.

It now begins to appear why the processes of magnetization and of hardening have common factors. A part, at least, of the forces[21] which hold the atoms together in solids are the magnetic forces between the magnetons or spinning negatrons. If by any means whatsoever—cold working, magnetic treatment or tempering—one can readjust the directions of spin of the magnetic gyrostats, at once both magnetic properties and hardness properties are changed. A change in one is not necessarily the cause of change in the other, but due to a common trigger as, for example, mechanical vibrations in the solid, both may be affected at one and the same time. Through tempering, one can certainly change the magnetic properties of bodies. Can one change the hardness of a body by magnetic processes? Such a point of view is supported by the relations between mechanical and magnetic characteristics which were expressed in the forepart of this chapter. Hardness is a mechanical characteristic of any solid body and must, therefore, bear a definite relation to the magnetic characteristics of that same body.

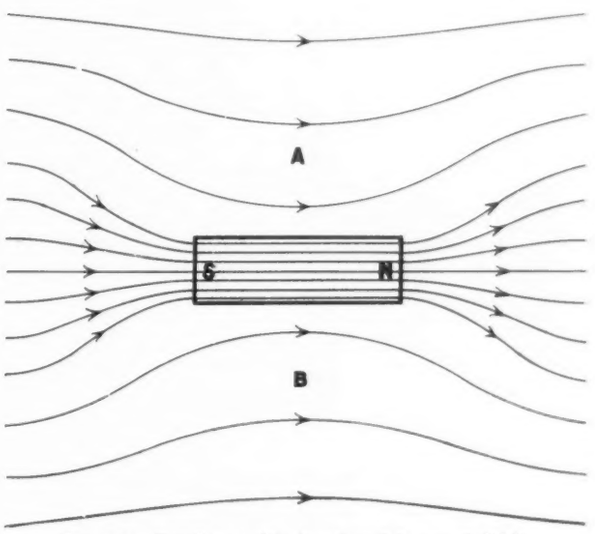


Fig. 269. Resultant of induced and imposed fields.

In speaking of magnetizing forces it becomes necessary to have a definite unit. The one adopted is called the oersted. A unit field intensity (one oersted) exists when that field exerts a force of one dyne on a unit (cgs) magnetic pole.

The field intensity may be represented graphically by drawing normal to a unit plane area a number of lines numerically equal to the value of the field intensity. Thus in Fig. 268 is shown a field intensity of 5, wherein 5 lines are drawn through unit area to represent a magnetizing force of 5 oersteds.

MAGNETIC QUALITIES

When a substance, like iron, for instance, is brought into a magnetic field the magnetic lines of force (or paths

[16]M. Faraday. Experimental Researches in Electricity. Bernard Onaritch, London, 1839. 3 Vols.
[17]C. Maxwell. A Treatise on Electricity and Magnetism. Clarendon Press, 1881. 2 Vols. 2nd Ed.
[18]H. Rowland. On the Magnetic Effect of Electric Conviction. *American Journal of Science*, Vol. 15, 1878, pages 30-38.
[19]R. W. Wood. The Production of a Magnetic Field by a Flight of Charged Particles. Philosophical Magazine, Vol. 3, 1902, page 659.
[20]J. C. Slater. Introduction to Chemical Physics. McGraw-Hill Book Co., New York and London, 1939. 521 pages.
[21]G. Lewis. The Magnetochemical Theory. *Chemical Reviews*, Vol. 1, 1924, pages 231-248.

along which the magnetic forces act) are increased. If one represents the field intensity in the manner described, and visualized in Fig. 268, then the number of lines of force in the iron will be represented by more lines per unit area than in the space were the iron removed. See Fig. 269. The ratio between the number of lines per unit area in the iron and the number of lines per unit area in the same space, were the iron removed, gives a value of the permeability factor μ used in Coulomb's equation given above. This value of μ will vary with the magnetizing force applied to such substances as iron, nickel, cobalt, manganese and their alloys, but in all of these substances mentioned μ will be greater than 1. Such substances are called ferromagnetics. In most substances μ is less than 1 and remains quite constant for varying values of ordinary field strengths. These bodies are classified as diamagnetic substances. On the other hand there is a group of solids in which μ is greater than 1 but unlike the ferromagnetic bodies, μ does not vary much in the ranges of ordinary magnetizing forces.

Bodies in which
constant $\mu < 1$ are called diamagnetic substances;
constant $\mu > 1$ are called paramagnetic substances;
variable $\mu > 1$ are called ferromagnetic substances.

Instead of calling the magnetic lines through a substance, like iron, lines of force it is customary to speak of these lines as the magnetic flux or the magnetic induction of the sample. The terms magnetizing force, field intensity and field strength are reserved as names for the magnetic field which is applied to the material being studied. The number of lines of magnetic flux or of magnetic induction per unit area through a ferromagnetic body like iron is usually represented by the letter B, hence $B/H = \mu$, the factor mentioned above. B is expressed in terms of gausses as the magnetizing force H was expressed in oersteds. The magnetic flux B is made up of two parts: first those lines due to H itself and second an increment due to the lines of force of the magnetons as they have been turned to coincide with those of the applied field. This may be expressed by the equation:

$$B = H + 4\pi\mathcal{J} \qquad \text{(Eq. for } B\text{)}$$

in which $4\pi\mathcal{J}$ represents the number of magnetic lines added by reason of the turning of the magnetons. $\mathcal{J}$ is called the intensity of magnetization and is equivalent to the pole strength per unit area induced on the end of the sample:

H = Magnetizing force or field intensity
B = Magnetic flux or induction
$\mathcal{J}$ = Intensity of magnetization

The value of $\mathcal{J}$ will depend upon how thoroughly the magnetons align themselves parallel to the applied field and upon the number of the magnetons.

If the equation for B is divided throughout by H, it takes on the form

$$\mu = 1 + 4\pi K$$

where K is called the factor of susceptibility as μ was called the factor of permeability.

Inasmuch as μ does not progress as a straight line function with the magnetizing force H, in the case of ferromagnetic bodies, the values of B will also not progress in the same way. This is shown in the curve OKM, Fig. 270, where the values of B are plotted against the corresponding values of H. This is called a normal induction curve and is composed of three parts as is exaggeratedly shown in Fig. 271. The part OP, Fig. 271, shows the increase in B as the magnetons begin to align themselves with the magnetizing force. In the section PQ the magnetons swing most rapidly and so B builds up rapidly at these values of H. From Q onward the point of saturation is approached and there is little added to the values of H by the alignment of the magnetons, because they are nearly parallel to the field for those field strengths beyond the point of saturation. The point Q is called the "knee" of the induction curve.

On reaching any point on the normal induction curve, which lies beyond the point of saturation, it will be found that on gradually reducing the magnetizing force H to zero the corresponding values of B will not lie along the original induction curve OKM in Fig. 270 but

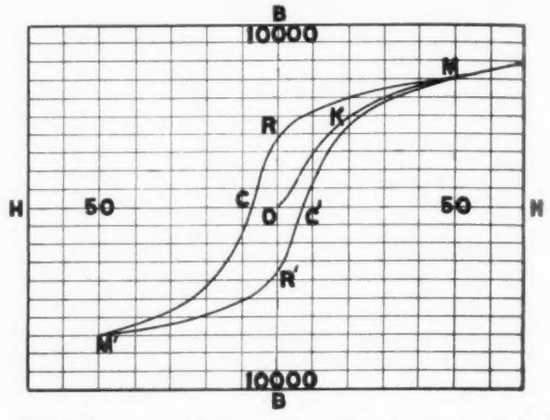


Fig. 270. Induction and hysteresis curve for a ferromagnetic body.

along MR. Furthermore, if the magnetizing force at the point $H = 0$ is reversed and the values of H again increased, the values of B for these magnetizing forces will lie along the curve RCM'. The material will now be magnetized beyond the point of saturation, but in the opposite direction to that which existed at M. Once more a decrease is made in the values of the magnetizing force H until it becomes zero. Again the field is reversed and increased until B attains a value represented by M again. During these values of H, B has changed its values along the curve $M'R'C'M$ and finally forms at M a closed curve called a hysteresis curve. The piece of iron has been taken through a complete magnetic cycle. Warburg[22] showed that in turning over the elementary magnets first in one direction and then in the other, a certain amount of energy was dissipated, a quantity which was directly proportional to the area of the hysteresis curve. For example hard steel will, in general, give hysteresis curves of large areas and soft steel small areas. In the hysteresis curve shown in Fig. 270 the values of B for $H = 0$ are OR and OR'. These values indicate the residual magnetism in the material. They are called the retentivity or remanence of the substance, a high value of which is essential for strong permanent magnets. The greater the values of the reversed fields, OC and OC', necessary to reduce B to zero, the greater is the coercivity of the metal. The greater these values OC and OC' become for any substance the less liable is that material to lose its residual magnetism when subjected to extraneous magnetic fields and mechanical disturbances.

The coercive forces OC and OC' which are measured by the strengths of the fields necessary to reduce the remanent magnetism to zero plays an important rôle in the relations between mechanical hardness and some of the magnetic properties. The coercive force has quite frequently been called the magnetic hardness of a body, an appelation which may lead to some misunderstanding.

[22] E. Warburg, Magnetische Unbersuchungen, *Wiedemann's Annalen der Physik und Chemie*, Vol. 13, 1881, pages 141-164.

because mechanical hardness and coercive force values do not always go hand in hand. For instance, Kussman and Scharnow[23] have shown that "in the case of alloys in solid solution (mixed crystals) in which the variation of the space lattice causes the mechanical hardness, the electric resistance, etc., strongly to increase in value in comparison to the pure metal, the coercive force is only inconsiderably altered, and that no direct relationship exists between the coercive force and the mechanical hardness of the alloy. The coercive force is shown to exhibit a strong increase in the case of heterogeneous mixtures where it is independent of the hardness. An explanation is given of the above through the assumption of an effect

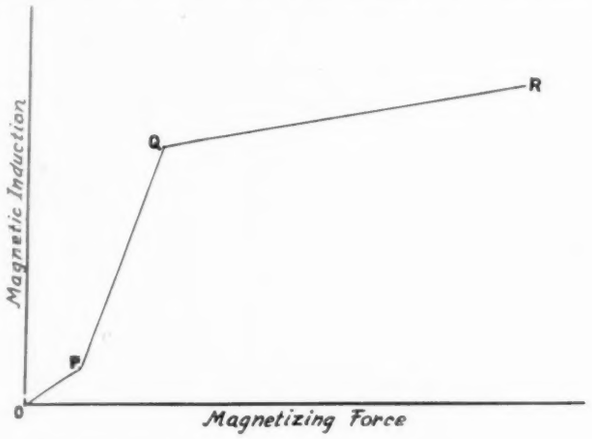


Fig. 271. The three parts to a normal induction curve.

on the ferromagnetism due to the tension created by contraction, which is primarily created by the different thermal expansion coefficients of the constituents of the mixture."

MECHANICAL STRAINS AND MAGNETIZATION

In discussing the relationships between magnetism and mechanical properties of substances we are, for the present, limiting ourselves to the ferromagnetic metals and their alloys. Some day our methods may be improved and refined so that we may push out into the fields of paramagnetic and diamagnetic solids. In any case we are dealing for the most part with polycrystalline substances, although single crystals may be had of the various ferromagnetic bodies. In dealing with crystalline materials we know that size of grain, angles of orientation of axes, temperature and many other factors cause the various physical phenomena of these polycrystalline bodies to vary as one condition after the other is imposed.

Andrade[24] suggests that "Smekal made a valuable generalization when he pointed out that the property of crystals could be divided into two classes: those, such as low-temperature ionic conductivity, which were largely influenced by small irregularities or impurities, and others which were largely independent of crystal individualities, that is, with which very consistent measurements could be obtained on unselected specimens. The former he called structure-sensitive, the latter structure insensitive." For instance, a single crystal of pure copper about the size of an ordinary pencil will, unless held flat in the palm of one's hand, sag at once into a U-shaped specimen. Its own weight when supported just at the ends would cause its slip planes to glide over one another and thereby increase its mechanical strength by about 50%. A single crystal of copper is structure-sensitive. A characteristic of single crystals is the great hardening produced by strain. One is reminded of Jeffries' and Archer's[25] theory of slip hardening when the slip planes move over one another. In spite of all the work which has been done upon hardness, the theory of hardening is still far from being in a satisfactory state. The recent work of Andrade, Becker, Brindley, Chalmers, Wood and others[26] seem to point toward a partial solution in the strains produced by movements of slip planes over each other and particularly by the deviations from the ideal lattice. Becker[27] has paid particular attention to the internal strains which help to correlate magnetic and mechanical phenomena in the same material. He has pointed out repeatedly that the sciences of the mechanical and magnetic properties of metals have a remarkable similarity in their development. "In each of them, there is one group of properties (a) which is susceptible of theoretically exact treatment by rigorous methods, while the theory of the other groups (b) is vague and even in the most favorable cases only qualitative. Unfortunately it is the properties in the second group which are of particular interest in most practical cases and which lead to the typical differences between materials. In mechanics the density and elastic constants belong to the first group, in ferromagnetism the saturation intensity and the Curie temperature. In the second group (b) are the critical shear stress" [the stress sufficient to produce a fixed (extremely small) rate of flow] "and the elastic yield point in mechanics and the permeability and coercivity in magnetism."

Becker goes on to show that most of the substances with which we are concerned are somewhat similar as regards their properties in group (a) but those in group (b) can be altered several hundred-fold by apparently small additions to the substance. This he attributes to the fact that in the first case we are concerned with a group of properties which concern the ideal lattice while in the second the properties depend upon deviations from it. He would sum up these differences as being due to "internal strains" which mean in the widest sense deviations from the ideal lattice.

In the beginning of this serial quite a number of theories of hardening were discussed. None of them gave a complete picture, but they need to be kept in mind as one seeks for a comprehensive theory. The more recent discoveries concerning lattice structures and deviations from ideal structures add greatly to this more complete story in the theory of hardening. Once we understand how hardening is produced by the several methods now available, the better we shall be able to define hardness with some degree of clarity. The work of Becker, both from the theoretical and from the experimental point of view, emphasizes the interrelations between the magnetic and the mechanical properties of ferromagnetic bodies. It is with this phase of hardness testing that the following pages are concerned. The theories discussed in the April 1937 article, the additions to our knowledge of lattice structures in single and polycrystalline materials still leave one point for further emphasis and that is what some authors call atomic concentration.

After all, matter in the solid state is like a fisherman's net: an awful lot of holes held together by some string. "Matter is also a lot of holes retained within a gossamer lattice structure of atoms." Now if all of the holes could

[23] A. Kussman and B. Scharnow. Über die Koerzitivkraft. I Teil: Koerzitivkraft und mechanischen Harte. *Leitschrift für Physik*, Vol. 54, pages 1-15, 1929. Quotation from S. G. B. *Science Abstracts*, Sec. A, No. 2282, Vol. 32, page 641, 1929.

[24] E. N. da C. Andrade. Glide and Hardening in Metal single Crystals. *Proceedings of the Royal Society*, Vol. 51, Pt. 5, 7-page preprint, 1939.

[25] Z. Jeffries and R. S. Archer. The Science of Metals. McGraw-Hill Book Co., New York and London, 1924, pages 403-448.

[26] These investigators and others contributed to a special symposium on "Internal Strains in Solids" held in the H. H. Wills Physical Laboratory, University of Bristol, Bristol, England, July 11-13, 1939.

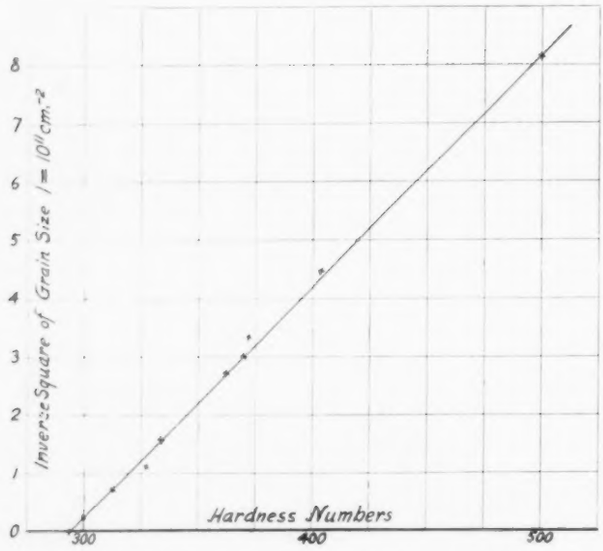


Fig. 272. Relation between grain size and hardness numbers.

be squeezed out and nothing left but the atoms, the number per cubic centimeter would be increased tremendously and the resistance to penetration augmented greatly—augmented to such an extent that penetration by ordinary matter would perhaps be "impossible." For if the atoms themselves are only slightly compressible and no interatomic space exists into which the atoms may be pushed it follows that resistance to penetration (hardness) is thereby enhanced. As indicated earlier in this study, density is measured by the number of negatrons, protons and neutrons which one can crowd into a cubic centimeter of space and these are the fundamental elements from which all atoms are created. It would appear from observations made on wood, marble, steels, copper, etc., that the interstitial spaces, whether between atoms, molecules, domains or crystal grains, have a great deal to do with the hardness of the material.

Lasarev[27] states that "the proportionality between hardness and atomic concentration (i.e. the reciprocal of atomic volume) follows from the assumption that the mutual attractive force of the atoms of different elements is the same function of the distance between them." The recent X-ray study of glass has shown it to consist of an irregular semi-crystalline structure in which the intercrystalline space has been made a minimum and no easy planes of slip. May not these factors indicate why glass is so hard? One wonders why diamond is so hard. Bragg[28] says, that "in the perfect symmetry and consequent effectiveness of the forces which binds each atom to its place" may be seen "an explanation of the hardness of the crystals."

In a series of three popular articles Professor French[29] has tried to explain the hardness of carbon in the diamond crystal and also of silicon which is to be found in the same column of the table of Chemical Elements. He considers that the three important factors in the formation of alloys are (1) the type of crystal lattice, (2) the number of electrons in the outer layer or shell and, (3) the size of the atom. These factors are then used in an attempt to explain the hardness of carbon in the diamond form, of silicon and of the combination of carbon and silicon in carborundum. Wood[30] studied the hardness of the same steel when given different grain sizes. The results showed that the smaller the grain size the harder the steel. Fig. 272 shows this relation in which if S represents the average grain size (proportional to diameter of grain) then the hardness may be expressed by the equation

$$H = K/S^2, \; K = \text{constant}.$$

There is implied in the study that the smaller the grain the more closely the grains snuggled together and increased the hardness. This seems to be the sort of material to which Becker's theory would best apply in correlating magnetic and mechanical properties.

The importance of interstitial space is emphasized by Lord Rayleigh[31] in some observations he made on marble. He found that heating marble increased the distance between the grains and thereby decreased the rigidity and the ultimate strength. Unfortunately he did not take into account the moisture with which marble always seems to be associated under normal atmospheric conditions.

Pöschl[32] contributed along this line by saying that the density of a crystalline solid is a better gage of the hardness of a body than is its crystalline symmetry. In this connection one wonders about the relative hardness of quartz in its natural (crystal) state and in its fused condition.

Before leaving these various contributions to the theories of hardening there is one paper[33] to which attention should be drawn. Throughout the more recent contributions to the subject of hardness one hears more and more about "solid solutions," "mechanical mixtures" and "chemical combinations." Bohler[33] has differentiated between these various aggregates in such a satisfactory way that it may be a help for many. He points out how a lump of sugar drops to the bottom of a glass of water under the force of gravity. Gradually it dissolves and diffuses uniformly throughout the water. In the process of diffusion the constituent particles have had energy imparted to them so as to rise against the force of gravity. The particles of sugar are now pounding the walls of the glass as well as those of the water in their eternal dance of the molecules. This means an added pressure on the walls of the glass which is a measure of the osmotic pressure. In the case of steel (0.8% carbon) above approx. 1500°C., there is formed martensite, a definite solution of carbon in iron, which if cooled suddenly by quenching solidifies as a solid solution. It is quite different from what ensues when the metal is cooled slowly. In the latter case we have a group of mixed crystals. Bohler says that the well-known increase in hardness due to quenching can't be attributed to increased atomic concentration but rather to the strains set up in the process of quenching. While he does not make clear how osmotic pressure works in a solid solution to increase the hardness, one could argue from this paper, however, that the increased pressure due to osmosis still held the lattice system in a state of internal strain. Again, it is these internal strains which in many cases affect the mechanical and magnetic properties of substances.

From whatever viewpoint one observes the factors involved in the mechanical and magnetic properties of ferromagnetic bodies, the strains set up in the materials play an important rôle.

[27]P. Lasarev. Relationships between Hardness and the optical and thermal Properties of Elements. Bull. Acad. Sci. Russie, Vol. 6, pp. 1259-1260, 1918. Quotation from Brit. Chem. Abstracts, Vol. A, p. 116, 1926.

[28]W. H. Bragg. X-rays and Crystalline Structure. *Science*, Vol. 40, 1914, pages 795-802.

[29]S. J. French. The Science of Alloy Building. *Scientific American*, Vol. 158, 1938, pages 78-80, 152-155, 340-342.

[30]W. A. Wood. X-ray Study of Grain Size in Steels of Different Hardness Values. *Philosophical Magazine*, Vol. 10, 1930, pages 1073-1081.

[31]Lord Rayleigh. The Bending of Marble. *Proceedings of the Royal Society (A)*, Vol. 144, pages 266-279, 1934.

[32]V. Pöschl. Uber Beziehungen zwischen Chemischer Zusammensetzung, Kristallform, Harte and Dichte. *Zeitschrift für Anorganischen Chemie*, Vol. 59, 1908, pages 102-107.

[33]O. Bohler. Ueber die Molecularen Vorgange beim Harten. *Zeitschrift für Werkzeugmaschinen und Werkzeuge*, Vol. 11, 1906-07, pages 32-34.

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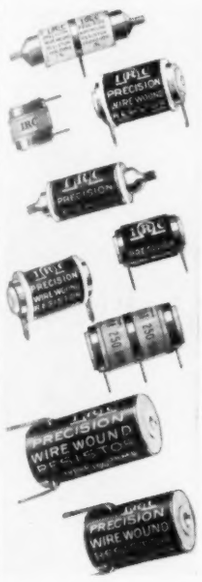

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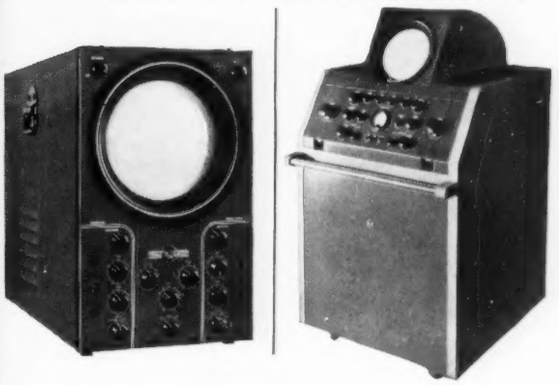

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New X-Ray Tube Makes Microsecond Radiographs

DEVELOPMENT of a new cold-cathode ultra-high-speed X-ray tube that makes millionth-of-a-second radiographic exposures was described to members of the American Physical Society on June 21 in Pittsburgh by Dr. Charles M. Slack, research physicist for the Westinghouse Lamp Division's research laboratories at Bloomfield, N. J., where the tube was developed. This apparatus makes possible X-ray motion pictures, enabling man to see into rapidly moving opaque objects, or to study the internal strain effects of sudden forces on such objects.

The new X-ray tube contains three elements: a standard anode; a small oval-shaped metal cathode; and an auxiliary electrode which serves as a trigger to initiate the discharge of electrons when the tube is activated but immediately thereafter assumes the rôle of focusing cup. The trigger element permits anode and cathode to be separated sufficiently to forestall formation of a low-voltage arc discharge which would prevent production of X-rays.

Circuit operates as follows: Capacitors are charged to about 90,000 volts. A spark gap in series with the tube withholds voltage from the tube until an impulse is given from an auxiliary timing circuit. When the timing circuit is broken, such an impulse is created and is added to the main voltage of the capacitors. Addition of the impulse causes the capacitors to discharge across the gap and through the tube.

To help create an impulse which causes the capacitors to discharge at the desired instant, a strand of fine wire in the timing circuit is placed just ahead of the moving object to be radiographed. The X-ray tube is placed at one side, opposite the cassette containing the film, so that the object to be pictured is directly between tube and film, and as near the latter as possible. When moved, the object disturbs or breaks the wire and interrupts the circuit, creating the capacitor-discharging impulse. At that instant, momentary surge of X-rays is produced, and the radiograph taken.

In operation, the tube receives a momentary "jolt" of several hundred to approx. 2,000 amperes, at between 90,000 and 100,000 volts. Conventional types of X-ray tubes are usually operated with 0.5 amp. or less of current. Key to the ability of the new tube is the auxiliary electrode, which harnesses and puts to work a once-avoided effect—cold emission—which is caused by erratic flow of current from parts of the tube other than the heated cathode or filament.

Many possible applications, such as radiography of metals, will require more powerful tubes and equipment than those used in the laboratory tests. Westinghouse engineers are confident that such tubes and equipment can be built.

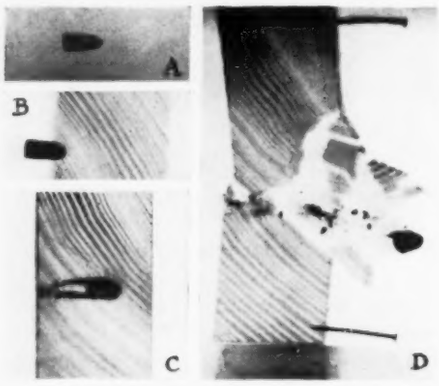

Fig. 1. Microsecond radiographs of bullets in flight in the air and during their course through blocks of wood, taken with the aid of the new Westinghouse ultra-high-speed X-ray tube.
(A) A .22 long rifle bullet in flight in air, seemingly standing still.
(B) A .22 long rifle bullet entering a block of wood.
(C) A similar bullet about two-thirds of the way through the plank. Notice trail of lead; wood is virtually sealing itself shut in wake of bullet.
(D) Another bullet of the same caliber emerging from a wood block, which it has literally exploded on emerging.

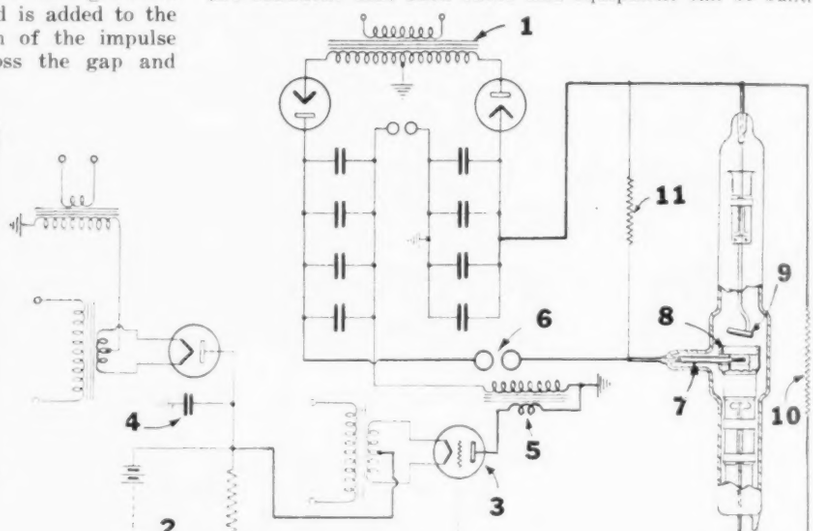

Fig. 2. Circuit diagram. High-voltage transformers 1 charge capacitors through rectifiers. Timing circuit is broken at 2, a negative charge on grid of thyratron 3 is dissipated; capacitor 4 discharges through primary of induction coil 5. This voltage is added to that of the capacitors, causing spark gap 6 to break down, and activate X-ray tube. Total voltage is then between cathode 7 and auxiliary electrode 8. Cold emission working across this narrow space causes electrons to be pulled from the cold metal of 7 to 8. As current starts, voltage between 7 and 8 diminishes, and electron stream from cathode "hot spot" on 7 is diverted to anode 9, focused by 8. X-rays are generated at 9 by impact of electron stream. Diminution of voltage is caused by choking action of high resistance 10. Resistance 11 is placed directly across capacitors and gap to insure breakdown at gap 6 consistent with its spacing.

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Chicago Instrument Society

At a dinner meeting of the Chicago Instrument Society, held on June 6 and attended by ninety members, the following Executive Committee of nine was elected:

Earl C. Rieger, International Harvester.
J. Lewis, Crane Co.
J. P. Dahlberg, Youngstown Sheet & Tube.
J. E. Douglas, Inland Steel.
W. Kagi, Western Electric.
R. N. Powell, Wisconsin Steel.
A. J. Perkins, Underwriters Labs.
W. Brock, Socony Vacuum.
J. S. Bogen, Universal Oil.

The meeting was addressed by Dr. L. W. Wallace, Director of Engineering & Research, Crane Co. on "Intelligence and Instruments."

An Instrument Calibrator

Concluded from page 187

Left to right, on the panel are: S-4 with d-c. ammeter binding posts beneath; R-18; 150- and 1500-volt d-c. binding posts; push button switches S-6 and S-7; function switch S-3 (the first large knob); light L-1 beneath it; on-off switch S-2, with pilot L-3 above and a-c. - d-c. switch S-1 below it. Still lower appears the milliammeter binding posts. The second large knob operates R-21; and lamp L-2 is just below. The next push button switch is S-5. Below and to its right are binding posts for all the remaining voltages. The next knob controls S-8 and has R-13 on its right. The last binding posts are for a-c. amperes.

Instruments references on equipment for calibration of electrical instruments: March 1938, page 93; April 1938, pages 103 and 111.

OPERATING INSTRUCTIONS

Connect the instrument to be checked to the proper terminals at the bottom of the front panel. Set the switches as given in the following table, for the range desired. Whenever it is used, R-21 is to be increased until the standard has its desired deflection.

15 volts d.c.: Push S-6 before increasing R-21. Turn R-21 counterclockwise before releasing S-6.

1500 volts d.c.: Push S-6 and S-7 before increasing R-21. Turn R-21 counterclockwise before releasing S-6 and S-7.

Range	*Control*										
	S1	S3	S4	S8	R18	R1	S2	R21	S6	S7	S5
1 ma. d.c.	1	1	1	..	1	..	on	increase	..	..	..
20 ma. d.c.	1	1	2	..	2	..	on	increase	..	..	..
100 ma. d.c.	1	1	3	..	3	..	on	increase	..	..	..
500 ma. d.c.	1	1	4	..	4	..	on	increase	..	..	..
50 ma. d.c.	2	1	5	..	3	..	on	increase	..	..	..
500 ma. d.c.	2	1	6	..	4	..	on	increase	..	..	..
15 volts d.c.	1	3	..	1	..	1	on	increase	push	..	..
150 volts d.c.	2	4	..	4	..	1	on	increase	push	..	..
1500 volts d.c.	2	4	..	4	..	1	on	increase	push	push	..
6 volts a.c.	2	4	..	2	..	2	on	increase	..	..	..
75 volts a.c.	2	4	..	3	.	2	on	increase	..	..	..
150 volts a.c.	2	4	..	4	..	2	on	increase	..	..	push
6 amperes d.c.	2	2	Turn on S2 and adjust left side wire rheostat.								
5 amperes a.c.	2	2	Turn on S2 and adjust right side wire rheostat.								

NOTE: The positions of R-1 and R-18 were determined by trial and then marked on the panel.

POSSIBLE MODIFICATIONS

Should a d-c. supply not be available, the entire outfit could be modified to operate on alternating current only. The ammeter rectifier output should be shunted to provide for milliammeter ranges. There is a voltmeter supply rectifier already. If such an arrangement is used, a Variac or similar variable autotransformer might well replace R-21.

The same general idea as has been herein incorporated could well be used with but a few standard instruments, by using shunts and multipliers with them, the latter to be connected to gang switches as parts of S-4 and S-8, for example.

In choosing the ranges of instruments to use, consideration must be given to the accuracy desired, and sufficient overlapping be provided. For d-c. instruments, an increase of ten in each step is sufficient: 0-10 volts, 0-100 volts, 0-1000 volts, etc. Because of the non-linear scales of a-c. instruments, a greater overlap is required if equivalent accuracy is wished.

Slide wire rheostats R-5 and R-6 depend somewhat upon the voltage of transformer T-1. They should have sufficient resistance to give a wide range of currents, while still having enough dissipating capacity. They receive their power from a 6-amp. battery charger which was built into the device.

The inclusion of a voltage regulator transformer is desirable for greater accuracy (to keep the deflection constant), especially if the line voltage fluctuates to any extent.

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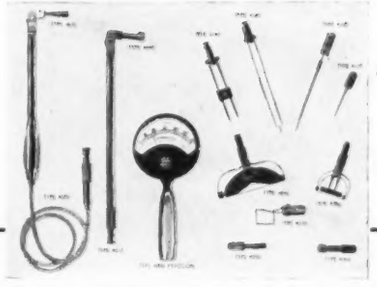

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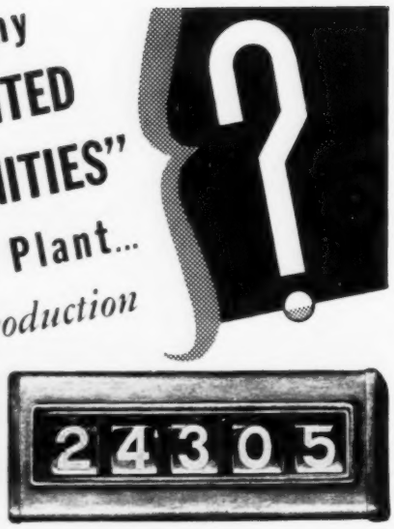

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Send in Your Group

LETTER TO THE EDITOR

"Education and Training Urgently Needed"

To the Editor of *Instruments:*

Allow me to add my small voice to the congratulations which you will undoubtedly receive on your June editorial. I am speaking not only for myself but for all the Esterline-Angus organization when I say that we agree 100% with your thesis of the urgent need for more men educated or trained in the field of instrumentation.

Our company makes only one specialty and we do not claim to have contact with all phases of instrumentation. But even in our little bailiwick, not a week goes by but what I am amazed at the ignorance of otherwise well trained and capable engineers as to what instruments can do for them, how instruments work, what they can and cannot do, how they should be cared for, and what is and is not good instrument practice.

I admit that part of my desire to see the men on the firing line in industry better informed as to instrumentation is a matter of professional pride. (But could a profession exist without pride?) I must also admit that a part of my desire in this direction is a matter of business.

But although my enthusiasm for your point of view does include these two factors, it really springs from something much broader: the fact that if American industry is going to be able to do the job that it is now called upon to do, and is going to maintain the American standards and way of life, it simply *must* employ in much more widespread fashion and more effectively all the tools of measurement and control that have so painstakingly been developed.

I took up this matter with my own Alma Mater a couple of years ago, suggesting a complete course in Instrumentation. The suggestion was courteously received but nothing was done—beyond passing the letter on to the heads of the various schools and recommending that more attention be given to the measurement phases of the work.

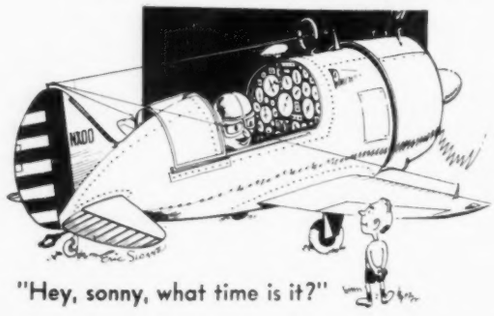
This is of little use, because the work of the different schools is not integrated. What is needed is *one* course where the student gets a broad view of instrumentation as a whole and of all different kinds of instruments as applied to all different kinds of problems; rather than learning about steam engine indicators in the Mechanical Engineering course, about flow meters in the Hydraulics course, about electrical instruments in the Electrical Engineering course, and about balances and optical pyrometers in Physics. As I understand it, that is your aim.

Go to it, Major! Our voice may not be very loud, but we certainly want to add it to the chorus.

THE ESTERLINE-ANGUS CO., INC.
R. J. KRYTER, *Sales Manager*

Indianapolis, June 20.

INSTRUMERRIMENT



"Hey, sonny, what time is it?"

Courtesy Jardur Import Co., New York
(From its aviation chronograph bulletin)

Aircraft Radio Installation Follows Modern Instrumentation Schemes

Developed by United Air Lines and now being installed in all the airline's planes, a new radio assembly includes a switchboard (Fig. 1) which makes the complete radio facilities of the plane available to the pilots merely flicking switches and a radio rack (Fig. 2) which saves 75 to 100 lbs. in weight.

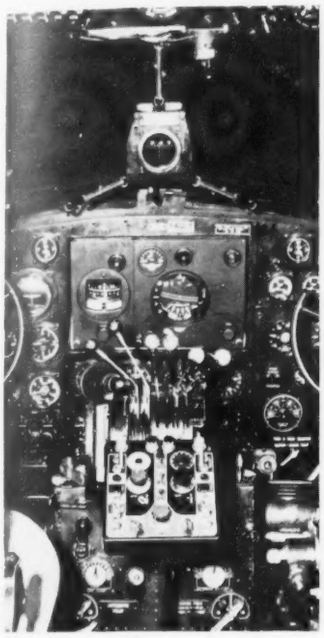


Fig. 1

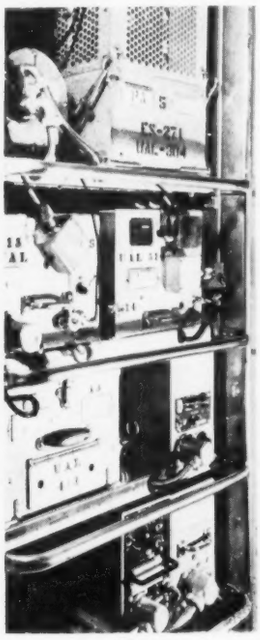


Fig. 2

Heretofore, airlines have scattered radio switches at various places in the control cabin and installed radio apparatus on shelves in the various cargo compartments, or wherever they could find a spot.

The radio switchboard, devised by P. C. Sandretto, superintendent of United's communications laboratory in Chicago, is only 8″ square and is as simple to operate as an office telephone switchboard. It is located on the control column within arm's reach of both pilots. No adjusting is necessary and none of the switches has contingent operation. The radio rack was designed by A. F. Trumbull, foreman of United's radio electric shop in Cheyenne. The combined device represents the first weight-saving apparatus since the introduction of aeronautical radio, according to J. R. Cunningham, director of communications for United.

Aeronautical Lending Library

A $50,000 endowment has been given to the Institute of the Aeronautical Sciences by Paul Kollsman and the Square D Company for founding an aeronautical lending library at Rockefeller Center, New York City. So announces Major Lester D. Gardner, Executive Vice President of the Institute, who further states that there will be available at once two thousand aeronautical books for loan by mail. (For consultation at its headquarters the Institute has, besides the new Paul Kollsman Lending Library, a reference library of over ten thousand aeronautical books.)

A bulletin to be issued periodically will review all new aeronautical books and will digest aeronautical articles, reports and pamphlets. The Paul Kollsman Library will in this way keep the specialists in the field informed on advances as well as provide them with books and magazines.

[The Square D Company recently acquired the Kollsman Instrument Company. Thus Paul Kollsman's famous "one-man firm" passed into history; but this merger evidently enables him to continue making aeronautical history.—EDITOR]

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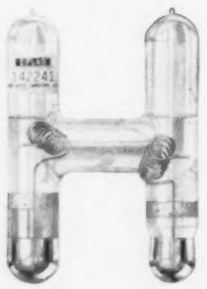

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FLASH! At the moment of going to press we learn that a radically new combination meteorograph-thermograph-humidigraph has just been brought out by the . . . Now where's the name of that manufacturer? . . . Beg pardon, the device isn't being produced commercially, only one having been built. . . . It *must* be new, however, for we've never seen anything like it! Wait a minute while we re-read the letter from Dr. Brown. . . . Oh, shucks! we made another slight error: the device isn't exactly a 1941 model.

EARL H. BROWN, PH.D.
CONSULTANT
CHEMISTRY INSTRUMENTATION
WANTAGH, NEW YORK

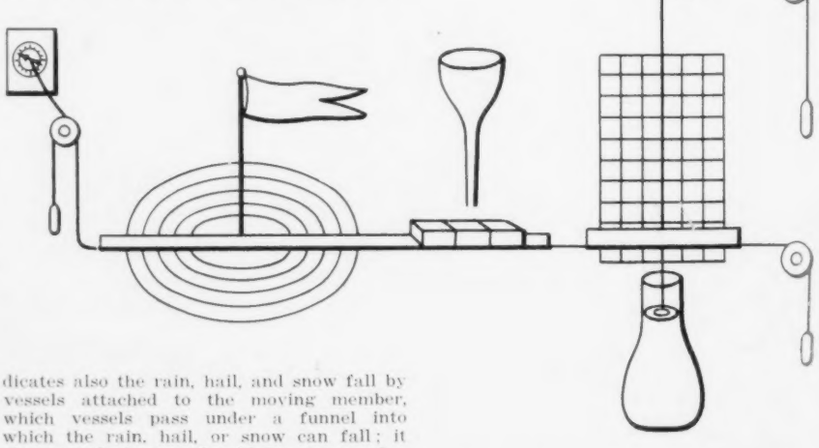
To the Editor of *Instruments:*

It has occurred to me that you might appreciate the example of instrumentation shown in the diagram herewith, which is a careful copy of the original illustration. It is described in the following passage:

"Outre le Collège que j'allois voir par curiosité, comme tous les autres, j'y allai encore plus pour voir M. Renes, grand Mathématicien quoy que petit de corps, mais des plus civils et des plus ouverts que j'aye trouvéz en Angleterre: car quoy qu'il ne veuille pas que ses pensées soient divulguées, il ne laissa pas de me dire fort librement celle de son Horologe du temps, qui fait mouvoir une règle, sur laquelle est attaché un rayon qui marque sur des cercles concentriques qui correspondent aux heures, tous les changements des vents qu'une Girouette indique, en les faisant tourner, et de mesme les pluyes, la gresle, et la neige par des vases attachéz à cette roue, qui passent à chaque heure sous un entonnoir, dans lequel il peut pleuvoir, neiger, or gresler; et le chaud et le froid pat un Thermomètre, qui fait hausser, ou baisser une tablette, contre laquelle un crayon de la règle susmentionnée allongée autant qu'il faut pour cet effet marque en travers les heures, comme la table marque en hauteur les changements, dont la figure ci-jointe est un grossier dessein."

which is so technically exact and so linguistically clear that it deserves a Pulitzer Prize—or something—but a portion of which I have freely translated as follows:

"The clock activates a bar to which is attached an arm which marks on concentric circles, representing hours, the changes of wind as indicated by a weathercock; it indicates also the rain, hail, and snow fall by vessels attached to the moving member, which vessels pass under a funnel into which the rain, hail, or snow can fall; it also records heat and cold by means of a thermometer which raises or lowers a chart against which presses a pencil suitably extended from the bar, the horizontal movement representing time, the vertical temperature."



The source? "Les Voyages de M. de Monconys"—a volume of travels published in 1695. It is in the form of a diary; the reference to instrumentation appears after the date of June 11, 1663, and the location mentioned is Oxford University or in that vicinity. . . .

Having been a reader of *Instruments* for a number of years I am aware that material of this nature does not ordinarily appear therein, but here it is nevertheless.

Sincerely,
EARL H. BROWN

[Thank you, Dr. Brown, and congratulations upon your ability to make out a text written in Old French and evidently printed with a sprinkling of typographical errors. —EDITOR]